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HENDRIK VAN BROEKHUIZEN

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HENDRIK VAN BROEKHUIZEN
DEPARTMENT OF ECONOMICS
UNIVERSITY OF STELLENBOSCH
PRIVATE BAG X1, 7602
MATIELAND, SOUTH AFRICA
E-MAIL: HENDRIKVANB@SUN.AC.ZA

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ABSTRACT

Procrastination is an almost archetypal phenomenon of human behaviour, the nature and prevalence of which may have severe implications for the foundations of Microeconomic theory and the rational actor model. This paper aims to assess why and how agents procrastinate in theory and what the implications of procrastination may be. It is argued that procrastination is a rational response to present-biased preferences and that the extent of procrastination, and the subsequent welfare implications thereof, depends on the degree of *conscientiousness* regarding one's own expected future self-control problems and the nature and requirements of the task with which one is assigned. The theoretical model proposed to analyse procrastination therefore parameterises the temporal evolution of present-biased preferences as a function of agents' levels of *conscientiousness*. It is found that *less conscientious* agents tend to procrastinate more than *more conscientious* agents, that uncertainty exacerbates the extent and compounds the implications of procrastinating behaviour, and, consequently, that procrastination is more likely to be welfare non-maximising the lower an agent's level of *conscientiousness* and the greater the amount of uncertainty that exists regarding the nature and requirements of the task with which the agent is assigned.

Keywords: procrastination, dynamic inconsistency, present-biased preferences, quasi-hyperbolic discounting, differential salience, conscientiousness, sophistication, naivety.
JEL codes: D01, D80, D91

*"Do not put your work off till tomorrow and the day after; for a sluggish worker does not fill his barn, nor one who puts off his work: industry makes work go well, but a man who puts off work is always at hand-grips with ruin."*

*- The Greek didactic poet Hesiod in 'Works and Days' (~800 BC)*

## 1. Introduction

Procrastination is an almost archetypal phenomenon of human behaviour that has manifested in various endeavours of life for millennia (Steel, 2007:67). Despite its pervasiveness, however, surprisingly little attention has been given to the causes and consequences of procrastination in the economic literature. Yet, if the psychological literature is to be believed, the prevalence of procrastination may well have severe implications for the very foundations of Microeconomic theory; not least for the rational actor model (Akerlof, 1991:2). For this reason, it is necessary to carefully consider whether the act of procrastination can be explained by, or reconciled with, time-consistent preferences and what the potential consequences of procrastination are for individual welfare.

The aim of this paper is to assess the theoretical welfare implications of procrastination on a multi-period divisible task in which the costs of performing the task are experienced immediately whilst the reward from the task, the size of which depends directly on the amount of effort put into its performance, is only obtained after the task has been completed. It is argued that procrastination is a rational response to present-biased preferences and that the extent of procrastination, and the subsequent welfare implications thereof, depends on the degree of *conscientiousness* regarding one's own expected future self-control problems and the nature and requirements of the task with which one is assigned. In accordance with the behavioural literature on procrastination, the use of the terms *conscientiousness*, *naivety*, and *sophistication* throughout this paper therefore refer to (a) the extent to which agents are aware that they will face self-control problems w.r.t. their future performance of tasks and (b) the extent to which they are aware of the nature and requirements of these tasks. The model proposed to analyse procrastination departs from previous models by parameterising the temporal evolution of present-biased preferences as a function of

agents' levels of *conscientiousness*.[1] This feature allows one to gauge, for different levels of *conscientiousness*, the extent to which procrastination may cause an agent to under-perform vis-à-vis personal, predetermined goals and subsequently suffer any losses to personal welfare.

Employing the new model of procrastination, the results from the illustrative examples of procrastinating behaviour in this paper show that *less conscientious* (i.e. more *naive*) agents tend to procrastinate more severely than *more conscientious* (i.e. more *sophisticated*) agents. This result is compounded by the degree of uncertainty that exists regarding the nature and requirements of the task with which the agent is assigned. As a result, the procrastinating behaviour of more *naive* agents is likely to be welfare non-maximising. By contrast, more *sophisticated* agents may be able to maximise their personal subjective welfare even when they do procrastinate.

The paper proceeds as follows: Section 2 provides an overview of the literature on some of the key concepts related to procrastination, including the relevance of procrastination to field of economics and the extent to which procrastinating behaviour can be reconciled with rational behaviour. Section 3 discusses the traditional approach to modelling procrastination and reviews some of the previous models of intertemporal preferences that have been used to investigate procrastination. Section 4 presents the development of the new intertemporal preference model that may be used to assess the welfare implications of procrastinating behaviour. Section 5 employs the model developed in Section 4 to analyse procrastinating behaviour in two illustrative examples. Finally, Section 6 comments on some of the issues related to procrastination and the limitations of the model developed in Section 4 and Section 7 concludes.

[1] The foundations of this model are predicated on former models of procrastination put forth by O'Donoghue and Rabin (1999, 2001 and 2006) and Fischer (1999 and 2001).

## 2. The Literature on Procrastination: Key Issues To Consider

### 2.1. Defining Procrastination

To analyze the causes and consequences of procrastinating behaviour, it is necessary to first understand precisely what procrastination entails. However, because the parameters that influence procrastination may vary between settings, a number of different definitions have been formulated in the psychological and economic literature.[2]

Some authors argue that, in certain instances, procrastination may potentially have beneficial consequences. This would be the case, for instance, if the postponement of certain actions, the outcomes of which are uncertain, forces an agent to accumulate more information and gain more certainty before taking action (Bernstein, 1998:15). However, in general, procrastination is described as behaviour with negative implications. Steel (2007:66) defines procrastination as the *"...voluntarily delay of an intended course of action despite expecting to be worse off for the delay*." Similarly, Solomon and Rothblum (1984:503) define procrastination as the *"...act of needlessly delaying tasks to the point of experiencing subjective discomfort."* Again, Akerlof (1991:1) describes procrastination as a pathological behaviour of task deferment, the consequences of which individuals do not fully appreciate at the point where deferment occurs.

Despite minor differences, most definitions of procrastination in the psychological literature emphasise three distinct elements (Schraw, Wadkins & Olafson, 2007:12). Firstly, procrastination involves the delay of a certain intended course of action. Secondly, the delay of this action is needless. Thirdly, this needless delay is counterproductive and, as such, leads to a loss of personal welfare. Accepting the first and second statements regarding procrastination, the primary aim of this paper is to assess whether, in theory, procrastination necessarily leads to a loss of personal welfare

[2] Consider, for example, a 40 year-old man who defers making personal contributions to his own pension and a 20-year old student who postpones studying for her exams. While the behaviour of both individuals may be characterised as procrastination, the underlying factors that inform their procrastinating behaviour are unlikely to be precisely the same. By extension, the extent and consequences of their respective procrastinating behaviours may differ.

or whether, under certain circumstances, it is possible for an agent to procrastinate without losing subjective utility.

## 2.2. The Relevance, Prevalence and Pervasiveness of Procrastination

Procrastination is a particularly common phenomenon in academia. In a study conducted by Solomon and Rothblum (1984:505), it is found that at least 46% of college students consider themselves serious procrastinators. Other studies have found that between 80% and 95% of college students regularly procrastinate when performing academic tasks (Steel, 2007:65). However, the manifestations of procrastination are not only prevalent in academia, but are also pervasive in other areas. For example, smokers wishing to give up the habit procrastinate when they claim that their current cigarette will be their last, only to make the same claim again when they light up their next cigarette. Similarly, people postpone taking out the garbage, put off returning important phone calls, delay purchasing certain goods and services, and defer many other actions because they anticipate the performance thereof to be unpleasant and/or because they believe that the cost of deferment will be negligible, especially if performance of the task does not seem to be particularly urgent at the specific juncture.

While the types of procrastination described above are commonplace, they do not, at first glance, appear to be particularly relevant to the field of economics. However, when people delay saving for their old-age they increase their dependency on state-provided pensions – a dependency which, ultimately, will most likely be funded by tax-payers. Similarly, if the largest producer of electricity in a country defers for years the maintenance of its power-plants and the expansion of its capacity to provide electricity, that country's entire economy may, many years later, suffer severely as a result of widespread rolling blackouts. In these examples, the economic implications of procrastination are clear: not only may deferment of certain tasks result in a loss of personal welfare for the procrastinating agent(s), but it may also materially affect social welfare.

Procrastination may also be relevant to the field of economics in a more insidious way. Specifically, if it is found that procrastination violates the economic assumption of rationality, its pervasiveness may undermine the most essential underpinnings of

microeconomic theory. As discussed in the following section, this may very well be the case.

## 2.3. Procrastination and Rationality

From a psychological perspective, procrastination is caused by a combination of intrinsic and extrinsic factors that incentivise the unnecessary delay of tasks which are regarded as aversive in some way (Ross, 2009:2).[3] In general, this aversiveness stems from the fact that performance of the task requires the input of effort and/or time. However, while task aversiveness may be an important correlate of procrastination, it alone cannot explain why procrastination occurs. After all, if one accepts that individuals have time-consistent preferences, as microeconomic theory suggests, then an agent's aversion to the performance of a task today will be the same as her expected aversion to the performance of the task tomorrow and indeed the day thereafter (O'Donoghue and Rabin, 1999:103). In this context, task aversion in itself can therefore only explain whether or not an individual is inclined to perform a task at all.

Akerlof (1991:1) purports that procrastination occurs because present costs and rewards have *undue salience* relative to future costs and rewards. That is, people perceive the present costs and/or rewards of performing an action more vividly than the future cost and/or rewards.[4] However, this salience can only be classified as *undue* if *a priori* judgements regarding the magnitude of current costs/rewards relative to future costs/rewards are revealed to be incorrect *ex post*. Therefore, it would be more prudent to refer to Akerlof's argument as one of *differential*, rather than *undue*, salience. Given this differential salience, task aversion becomes a plausible partial cause of procrastination. An agent may be more averse to performing a task today than in the future if the costs of performing the task today are perceived more vividly than the costs of performing the very same task in the future. Expecting that future costs will be less than today's, the agent has an incentive to postpone the performance of the task until a

[3] According to Steel (2007: 67), personality traits (including an individual's conscientiousness regarding his/her own self-control problems) and task characteristics (including the timing and structure of rewards and punishments) respectively represent the most important intrinsic and extrinsic factors that influence procrastination.

later time. However, when that time arrives, the agent faces exactly the same differential salience problem and once again has an incentive to postpone the task to an even later time.

Two important points flow from this description of salience–induced procrastination. Firstly, procrastination constitutes a self-control problem (Ariely and Wertenbroch, 2002:219). On the first day, the agent makes an implicit commitment to perform the task later, only to abandon this commitment when that later time comes. The agent thus experiences an intertemporal preference reversal: initially she prefers to perform the task at a later time, but when that time arrives she again prefers to perform the task not then, but later. Secondly, the agent's failure to anticipate this preference reversal, and indeed any preference reversals that follow, suggests that she is less than fully aware of the extent of her self-control problem(s) (Asheim, 2008:4).

If Akerlof's (1991:1) *differential salience* hypothesis is correct, then procrastination violates both assumptions of economic rationality, namely: consistent intertemporal decision-making and exploitation of full information when forming expectations of the future. The first assumption is violated, almost by definition, when differential salience gives rise to preference reversals which reveal dynamic-inconsistency in decision-making. Secondly, when agents repeatedly procrastinate because they (a) are not fully aware of their self-control problems or (b) because they failed to learn about the dynamic inconsistency of their preferences when they procrastinated on former tasks, their expectations certainly are not formed rationally. Instead, since these agents assign greater relative weight to earlier moments as they come closer than later moments, their preferences may more aptly be described as present-biased (O'Donoghue and Rabin, 1999:106).

## 3. Modelling Procrastination

Both the cognitive psychology and experimental economics literatures have provided compelling evidence of the existence and pervasiveness of present-biased preferences.[5] Formal models of procrastination that have been developed in the economic literature have therefore included the modelling of dynamic-inconsistency and present-biased preferences.[6&7] However, while traditional economic intertemporal preference models have been able to capture the fact that agents are impatient by using exponential discounting, this approach explicitly assumes that preferences are intertemporally consistent (O"Donoghue & Rabin, 1999:106). Therefore, it is argued that intertemporal preferences are more aptly captured by hyperbolic discounting (Ainslie, 1974:485; Loewenstein & Thaler, 1989:192; Loewenstein & Prelec, 1992:580).

### 3.1. Setting-up the model of Procrastination

The vast majority of intertemporal preference models that investigate procrastination are predicated on a simplification of hyperbolic discounting called *quasi-hyperbolic* discounting.[8] Also referred to as *(β, δ) – preferences*, this quasi-hyperbolic discounting approach not only captures the essence of present-biased preferences, but also largely preserves exponential discounting's analytical tractability (O'Dognohue & Rabin, 1999:106; Fischer, 1999:8). In discrete time, the basic *(β, δ) – preferences* model may be expressed as:

$$U^t(u_t, u_{t+1}, \dots, u_T) = u_t + \beta \sum_{\tau=t+1}^{T} \delta^{\tau-t} u_\tau \qquad \text{for} \quad t \in [1;T] \;;\; 0 < \delta \leq 1 \;;\; 0 < \beta \leq 1$$

In this model, as in the traditional exponential discounting model, the parameter $\delta$ represents the time-consistent long-run discount factor. On the other hand, the

[5] See, for example, Loewenstain and Prelec (1992), Gilovich, Kerr and Medvec (1993), Sasaki *et al* (2008), Bisin and Hyndman (2009), and Shu and Gneezy (2009).
[6] See,O'Donoghue and Rabin (1999, 2001 and 2006) and Fischer (1999).
[7] The exception to this rule is a paper by Carolyn Fischer (2001) in which procrastination is modelled with time-consistent preferences. However, as Fischer herself notes in a follow-up paper: *"...in this fully rational model, the implicit rate of time preference...needed to generate serious procrastination is much larger than is typically assigned to people in standard economic models."* and *"...the perception that procrastination is problematic cannot be explained with time-consistent preferences."* (Fischer, 1999:3)
[8] This approach was first suggested by Phelps and Pollak (1968:186).

parameter $\beta$ captures the extent to which the future is discounted relative to the present or, put differently, the magnitude of the present-bias in preferences. From the above it should be obvious that when $\beta = 1$ the model reduces to a simple exponential discounting model with time-consistent intertemporal preferences. However, when $\beta < 1$, greater weight is assigned to the present relative to the future. The $\beta$-parameter thus fully captures the dynamic-inconsistency suggested by present-biased preferences. (O'Dognohue & Rabin, 1999:106)

## 3.2. Solving the model of Procrastination

While the basic *(β, δ)* – *preferences* model presented above provides a basis for analyzing the present-biased preferences that incentivise procrastination, it does not address the other key component needed to explain persistent procrastination - i.e. that procrastinating agents must, in some form or other, possess less than full *conscientiousness* regarding their own self-control problems. Yet, to assess the welfare implications of procrastination it is necessary to incorporate this component when modelling procrastination. To this end, models of procrastination usually employ a picoeconomic approach whereby agents are divided diachronically into a sequence of interacting *selves* and then assumptions are made regarding their levels of *conscientiousness* (Ross, 2009:4). Put more simply, the picoeconomic approach entails that a single agent is divided into multiple *selves,* where each *self* corresponds to a specific time period. The agent's degree of conscientiousness can then be modelled by making assumptions regarding how accurately former *selves* anticipate the preferences of later *selves*. The agent must thus choose a course of action that maximises her current preferences conditional upon the fact that her future selves are effectively in control of her behaviour (O'Dognohune & Rabin, 1999:106).

Previous models of procrastination in the economic literature have considered three generic levels of conscientiousness for agents with present-biased preferences. Firstly, *sophisticated* agents or *Sophisticates* are fully aware of their future selves' preferences and, therefore, of their future self-control problems (O'Dognohune & Rabin, 1999:106). Secondly, *naïve* agents or *Naïfs* believe that their future selves' preferences will be fully consistent with their current preferences. That is, they are wholly unaware of their future self-control problems (O'Donoghue & Rabin, 2008:162). Lastly, partially *naïve*

agents or *Partial Naïfs* are aware that they may face self-control problems in the future, but they are not fully aware of the extent of these self-control problems (Asheim, 2008:4).[9]

To determine how much agents with present-biased preferences procrastinate, it is necessary to define a perception-perfect strategy for each level of *sophistication*. This perception-perfect strategy describes an agent's optimal decision path given both current preferences, and the perception of future preferences and subsequent behaviour (O'Dognohune & Rabin, 1999:106). Given these perception-perfect strategies, models of procrastination may then be solved using complicated game-theoretical modelling and backwards induction (O'Dognohune & Rabin, 2001; Asheim, 2008).

## 4. A New Model of Procrastination

One of the shortcomings of the models of procrastination described in Section 3 above is the categorical classification of levels of *sophistication*. In these models, agents are either separated into two extreme categories, *Complete Sophisticates* and *Complete Naifs*, or, if they cannot accurately be described by either of these extremes, are placed into the single, imprecisely defined intermediate category of *Partial Naïfs*. Evidence from the experimental economic literature on procrastination suggests, however, that procrastinators are neither fully *sophisticated*, nor fully *naive*. Instead, it is found that agents exhibit, in mixed variations, elements of both *sophistication* and *naivety* when they procrastinate (Ariely and Wertenbroch, 2002:224; DellaVigna & Malmendier, 2006:20).

These findings suggest that agents are generally aware that they will face self-control problems when they procrastinate, but that they possess varying levels of *conscientiousness* regarding the true extent of these self-control problems. Accepting the validity of these findings, the single intermediate category of *partial naivety*, as it is

[9]Because *sophistication* and *naivety* represent opposite ends on the scale of conscientiousness, in the remainder of this paper, they are respectively used as terms to refer to levels of conscientiousness which lie closer to that of *Sophisticates* and levels of conscientiousness which are closer to that of *Naïfs*

defined and used in previous models of procrastination, can no longer suffice for modelling procrastination by agents who are neither *Complete Sophisticates* nor *Complete Naifs*. The aim of this section, therefore, is to develop a new model of procrastination wherein an agent's degree of *sophistication* or *naivety* is fully parameterised on a continuous scale. This parameterisation allows one to gauge how marginal changes in an agent's level of *sophistication* affect the extent of the agent's procrastinating behaviour and its subsequent implications for personal welfare.

## 4.1. Some Preliminaries

This section specifically considers procrastination on a multiple-stage, divisible task with a deadline. The performance of this task requires repeated input(s) of effort and/or time which yield disutility at the point where effort and/or time is expended.[10] In other words, the costs of performing the task are experienced immediately. The task also produces a reward, the size of which depends directly on the agent's cumulative inputs into the performance of the task. However, this reward is only received if the task is completed and then only after the task-deadline. While the reward thus yields utility, this utility is only experienced after the task-deadline. In other words, the reward from performing the task is delayed.

The features described above are characteristic of a typical academic research-paper which a student is assigned to complete for grading before a certain deadline. This example is therefore often used throughout the following two sections to simplify and facilitate the discussion on the development of the new model of procrastination.[11] The aim in the development of this model is to keep its assumptions and dynamics as close to reality as possible while maintaining sufficient tractability for its results to be readily interpretable.

[10] I.e. labour is assumed to be aversive.
[11] It is important to note, however, that the results from this model may be generalised to any other tasks or actions that are characterised by the same features as the research paper.

## 4.2. Model Setup: Rewards, Costs and Constraints

Suppose a representative agent called Sarah, is given on day $t = 1$ a task to perform over a total of $T$ days. If Sarah performs the task before the deadline, she will receive a reward in time $S$, where $S \geq T$. The value of this reward, $F$, is an increasing function of the cumulative number of hours that Sarah works on the task over the $T$ days before the deadline.[12] That is:

$$F = F\left(\sum_{t=1}^{T} w_t\right) \quad ; \quad F'(\cdot) > 0 \quad ; \quad F''(\cdot) < 0$$

where $w_t$ is the number of hours that Sarah works on the task on day $t$ and $F(\cdot)$ is strictly increasing and concave.

Based on various intrinsic and extrinsic variables, including Sarah's intellectual capacity, her personal ambitions, the time constraint that she faces and her supervisor's expectations, Sarah sets her own, subjective predetermined *"goal"* reward, $F_G$.[13] Of course, in order for Sarah to obtain this *"goal"* reward, she will need to work the number of hours that will set $F = F_G$. Suppose that the true total number of hours that Sarah would need to work in order to obtain $F_G$ is equal to $R$ such that $F(R) = F_G$. Also assume, for now, that, in the absence of any uncertainty, Sarah is able to correctly estimate the value of $R$.[14]

Sarah realizes that she needs to work $\sum_{t=1}^{T} w_t = R$ hours in order to receive $F_G$. However, because it is assumed that labour causes disutility, Sarah also realizes that her labour will incur a cost, $C$, which is an increasing function of the cumulative number of hours that she works on the task over the $T$ days before the deadline. Specifically:

$$C = C\left(\sum_{t=1}^{T} w_t\right) \quad ; \quad C'(\cdot) > 0 \quad ; \quad C''(\cdot) > 0$$

[12] Unfortunately, since effort cannot be readily measured, it has to be assumed for simplicity that the number of hours worked on the task fully captures the amount of effort and/or time that agents put into the performance of the task.

[13] If the task involves the writing of a research paper, for example, Sarah's goal value for her reward may, for instance, be to get an *A* grade for her paper.

[14] The implications of relaxing this assumption are discussed in Section 5.2 below.

where $C(\cdot)$ is strictly increasing and convex.[15] Therefore, if Sarah works $R$ hours, her labour will not only yield her desired reward, $F_G$, but will also incur a cost of $C = C(R)$. However, for Sarah, this specific end justifies the means. This is so, by definition, since Sarah otherwise would not have chosen $F_G = F(R)$.[16] Put differently, for Sarah the value of the goal reward is at least enough to offset the costs of the labour performed in order to receive the goal reward. Formally:

$$\textbf{\textit{Lemma}}\ \mathbf{1}\text{:}\quad F(R) - C(R) \geq 0$$

Since Sarah determines her own subjective goal reward, she would not be happy if she received a reward which is less than $F_G$, even if it implied that she would then need to work fewer than R hours and, therefore, expend less "effort" in order to obtain a reward. That is:

$$\textbf{\textit{Lemma}}\ \mathbf{2}\text{:}\quad F(R) - C(R) - [F(K) - C(K)] > 0 \qquad \forall\ R > K$$

Given Sarah's reward-cost preferences above, she must now decide how to structure the $R$ hours of work on the task over the $T$ days available to her. She is aware that the daily extraction rate of labour is ultimately constrained by length of the day and that, if she faced no other constraints, such as the need to sleep and eat, she would technically be able to work a maximum of 24 hours each day (Fischer, 1999:7). Of course, since she may well face other constraints on her time, this does not mean that she will be able to work 24 hours a day, but merely imposes two additional binding constraints on her behaviour:

$$w_t \leq h_t \leq 24 \quad and$$

$$\sum_{t=1}^{T} w_t \leq \sum_{t=1}^{T} w_t \leq 24T$$

where $h_t$ is the total number of hours available for work on the task on day $t$

[15] Herweg and Müller (2008:6) explain the reason for the convexity of this cost function by asserting that *"...the costs of effort are the opportunity costs of not enjoying leisure time. Making the standard assumption of decreasing marginal utility of leisure time is equivalent to assuming a convex cost function."*

[16] I.e., the agent chooses the goal reward that maximises subjective utility conditional on the amount of input needed to yield that reward.

## 4.3. Model Setup: Adding Intertemporal Preferences

The previous section depicts the preferences and constraints that agents face when assigned with the type of task described in Section 4.1. However, to model procrastination it is necessary to know how agents will structure their work on the task over the time available to them. To know the structure of agents' work, it is necessary to take cognisance of their intertemporal preferences.

From the discussion of differential salience in Section 2.3 and present-biased preferences in Section 3, it is clear that a model of procrastination must be able to account for *(β, δ) – preferences.* Furthermore, Fischer (1999:15) argues that differential salience may not only manifest temporally, but also spatially. That is, in addition to assigning greater weight to a present event relative to that same event in the future, agents may also assign greater weight to one type of event relative to another type of event even if they occur at the same time. The essence of this principle is illustrated by the concept of loss aversion according to which agents assign more weight to losses than to proportional gains (Schmidt and Zank, 2005:157). Thus, it may be the case that, in present-biased preferences, the weight assigned to present relative to future costs is not the same as the weight assigned to present relative to future rewards.

Given the features described above, the basic model of intertemporal-preferences with which procrastination can be analyzed may be expressed as follows. For $t \in [1; T]$ :

$$U^t(u_t, u_{t+1}, \dots, u_T) = \gamma\delta^{S-t}F\left(\sum_{t=1}^{T} w_t\right) - C(w_t) - \beta \sum_{\tau=t+1}^{T} \delta^{\tau-t}C(w_\tau)$$

$$\frac{\partial U^t(\cdot)}{\partial F(\cdot)} > 0, \qquad \frac{\partial U^t(\cdot)}{\partial C(\cdot)} < 0$$

$$F'(\cdot) > 0, \quad F''(\cdot) < 0, \quad C'(\cdot) > 0, \quad C''(\cdot) > 0, \quad \gamma \geq 0, \quad 0 < \delta \leq 1, \quad 0 < \beta \leq 1$$

Here, $\delta$ once again represents the time-consistent long-run discount factor for costs and rewards whereas $\gamma$ and $\beta$ respectively capture the salience of future relative to present rewards and the salience of present relative to future costs. The use of two distinct parameters to capture the differential temporal salience of costs and rewards means that one can also capture the salience of rewards relative to costs. When the rewards of

certain tasks are not clearly defined, for instance, it may be the case that, even after controlling for the timing-structure of costs and rewards, the costs of the task remains more salient than its rewards. In such an event the parameter $\gamma$ would be less than $\beta$.

## 4.4. Model Setup: Adding Conscientiousness

Up to this point, agents' levels of *conscientiousness* have not yet entered the model of procrastination. To introduce this key component, it is first necessary to carefully consider what *conscientiousness* implies. An example of real world behaviour put forth by Ariely and Werntenbroch (2002:219) serves to illuminate this issue:

> *"...well in advance of actually taking on the responsibility of writing a book, the benefits of completing such a task loom large, and the costs seem small. Consequently, authors take on such tasks.* ***But as the deadline draws closer****,* ***the saliency of the costs and benefits changes****. Authors* ***become increasingly aware*** *of the costs (the time needed for completing the task), while the benefits become increasingly less clear."* [emphasis added]

What Ariely and Werntenbroch (2002:219) describe here is an evolutionary process. Firstly, they point out the fact that preferences and the saliency of certain events are not stationary. Rather, they change with the passage of time. Secondly, the authors point to the fact that this change takes place as a result of agents' awareness of costs and rewards. To illuminate these points further, consider what happens when agents procrastinate on a task with a deadline. Agents cannot procrastinate forever. Sooner or later, they must make a decision to work on the task, or not at all. When agents postpone working on a task only to commence work closer to the deadline, this reveals the fact that the component of their preferences that initially incentivised procrastination is no longer operating as strongly.[17] Put differently, individuals stop procrastinating when the salience of the present relative to the future dwindles as the deadline approaches.

[17] This principle also applies when agents may already do some work on a task close to the assignment date, but leave the majority of the total workload until closer to the deadline.

This line of reasoning answers the question as to why procrastinators would stop procrastinating as the task-deadline approaches. However, it does not explain why certain agents stop procrastinating before others do. It is the contention of this paper that agents' levels of *conscientiousness* regarding their own self-control problems and the nature and requirements of the tasks they face determine the speed with which their present-biased preferences evolve into time-consistent preferences as the task-deadline approaches. Specifically, within the context of a divisible task with immediate costs and delayed rewards such as described in Section 4.1, it is argued that an agent's level of *conscientiousness* determines how fast future costs become as salient as present costs. Using the model presented in Section 4.2 above, this implies that, *ceteris paribus*, the greater an agent's *conscientiousness*, the faster $\beta$ converges to 1.[18] In the model of intertemporal preferences, an agent's level of *conscientiousness* is thus parameterised as follows:

$$U^t(u_t, u_{t+1}, \dots, u_T) = \gamma\delta^{S-t}F\left(\sum_{t=1}^{T} w_t\right) - C(w_t) - \beta^X \sum_{\tau=t+1}^{T} \delta^{\tau-t}C(w_\tau)$$

$$where\ X = \alpha^{\left[\frac{\frac{t(t-1)}{(\alpha+1\times10^{-10})\beta}}{T-\left(\gamma R-\sum_{i=1}^{t-1} w_i\right)/\left(\sum_{t=1}^{T} h_t/T\right)}\right]}$$

and

$$0 < \beta \leq 1 \quad ; \quad 0 \leq X \leq 1 \quad ; \quad 0 \leq \alpha \leq 1 \quad ; \quad \lim_{X\to 0} \beta \to 1 \quad ; \quad \lim_{X\to 1} \beta \to \beta$$

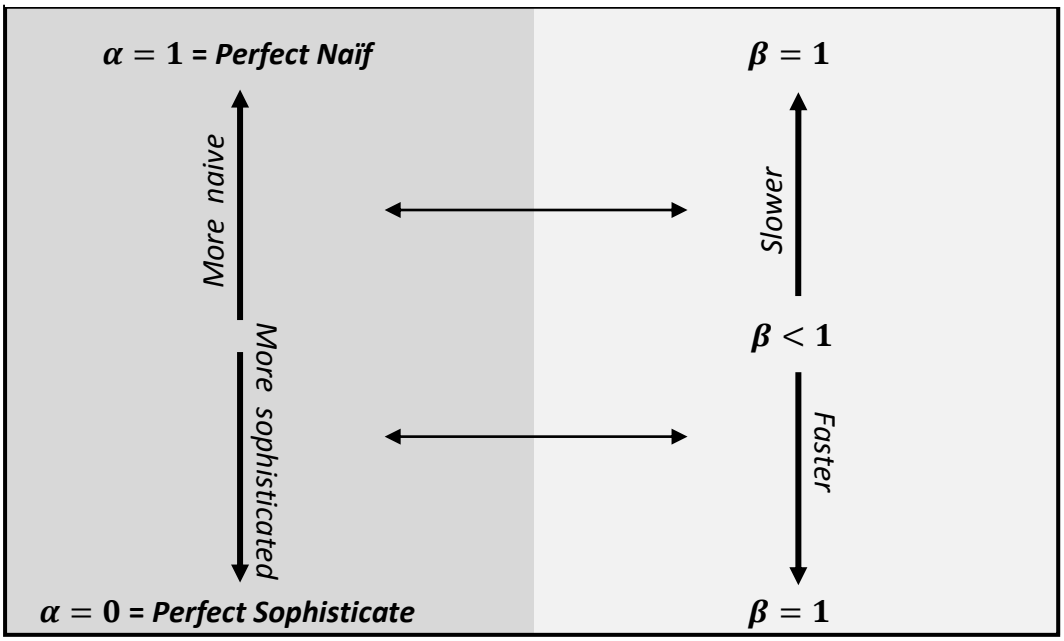
$$\frac{\partial X}{\partial \alpha} > 0;\ \frac{\partial X}{\partial \beta} < 0;\ \frac{\partial X}{\partial t} < 0;\ \frac{\partial X}{\partial T} > 0;\ \frac{\partial X}{\partial \gamma} < 0\ \ \frac{\partial X}{\partial R} < 0; \frac{\partial X}{\partial \sum_{i=1}^{t-1} w_i} > 0;\ \frac{\partial X}{\partial(\sum_{t=1}^{T} h_t/T)} > 0$$

$$\frac{\partial \beta}{\partial \alpha} < 0;\quad \frac{\partial \beta}{\partial t} > 0;\ \frac{\partial \beta}{\partial T} < 0;\quad \frac{\partial \beta}{\partial \gamma} > 0;\ \frac{\partial \beta}{\partial R} > 0;\ \ \frac{\partial \beta}{\partial \sum_{i=1}^{t-1} w_i} < 0\ ;\ \ \frac{\partial \beta}{\partial(\sum_{t=1}^{T} h_t/T)} < 0$$

[18] In the remainder of this paper, the rate at which β<1 approaches β=1 is referred to as the *speed of convergence*.

In this model, the $\alpha$-parameter captures an agent's level of *conscientiousness* or *sophistication*.[19] However, it is important to note that the way *sophistication* is defined here differs somewhat from other studies of procrastination. In other studies, the greater an agent's level of *sophistication*, the more aware that agent is of her own future self-control problems. However, if the agent is sufficiently aware that her self-control problems in the future may restrain her ability to satisfy her own subjective predetermined goal(s), she will have an incentive to do something about it. In fact, she will have an incentive to adjust the expectations of her own future behaviour, conditional on the changes in her task characteristics, such that her self-control problems may be overcome before they become a serious threat to her predetermined goal(s). Put differently, an agent's *sophistication* determines her awareness of, and sensitivity to, her present-biased preferences, the speed at which the task deadline approaches, and the size of the workload she faces relative to the time that she has available for the performance of the task. The greater her level of *sophistication*, the greater her response will be to changes in these variables, and the faster she will adjust her expectations of her own future behaviour.

*Figure 1 - Sophistication and speed of convergence of $\beta$*




[19] The $1 \times 10^{-10}$ term in the equation for X is included solely for the purpose of avoiding division by zero. The choice of this specific magnitude is somewhat arbitrary, since any negligibly small number would serve the same purpose without materially affecting the equation's results.

Figure 1 above illustrates that agents with values of $\alpha$ closer to 0 are more *sophisticated* than agents with values of $\alpha$ closer to 1 and that the rate at which $\beta$ converges to 1 is faster the more *sophisticated* an agent is. The model is also specified such that the convergence of $\beta$ to 1 quickens as the agent approaches the deadline, is slower the greater the amount of time that the agent has available to perform the task, is faster the greater the size of the workload and the salience of the task reward, and is slower the greater the amount of the workload that the agent has already completed. This makes intuitive sense since the size of the remaining workload, $(R - \sum_{i=1}^{t-1} w_i)$, relative to the amount of time available to perform the task, $T$, becomes more pressing as $t \to T$. However, as mentioned above, the speed of the response to changes in these variables and thus the speed of convergence depend on the agent's level of *conscientiousness*.

## 4.5. Model Setup: The Perception-based strategy

Given the setup of the model of procrastination above, a *perception-based strategy* for all agents can now be defined. Note that, unlike the perception-perfect strategy described in Section 3.2 above, the perception-based strategy does not necessarily describe the optimal decision path of the agent. Instead, the perception-based strategy simply describes how an agent chooses to structure work between the present and the future, based on present preferences and present perceptions of future preferences.[20]

Assume that in each period an agent can decide whether or not to work on the task. However, the agent will only work on the task on a given day if the total utility from working on that day is at least as great as the expected total utility from performing the same amount of work on any day thereafter.[21] Put slightly differently, to the question of whether or not an agent wishes to work on any given day, she can answer either *"yes"* or *"no"*. If she decides *"yes"*, then it is assumed that she will either work the total number of hours that is available for work on that day, $h_t$, or if $R < h_t$,, she will work the total number of hours needed to attain her goal reward. Using the language of O'Donoghue and Rabin (1999:108), a perception-based strategy can now be defined:

[20] In other words, the perception-based strategy may well lead agents to make decisions that are sub-optimal from the perspective of total subjective utility.
[21] If this were not the case, the agent would have an incentive not to work on that day, but rather to procrastinate.

*The perception-based strategy for all agents is a strategy* $\boldsymbol{s} \equiv (s_1, s_2, \dots, s_T)$ *that satisfies for all* $t \leq T$ $s_t = Y$ *if and only if* $u^t(w_t) \gtrsim u^t(w_\tau)$ *for all* $\tau > t$ and $w_t = w_\tau$

To illustrate how this perception-based strategy works, consider three distinct agents. Agent 1 has time-consistent preferences such that $\beta = 1$. For this agent, the level of *sophistication* is thus irrelevant. Both Agent 2 and Agent 3 have present-biased preferences such that $\beta = 0.5$. However, while Agent 2 is a *Perfect Sophisticate* with $\alpha = 0$, Agent 3 is a *Perfect Naïf* with $\alpha = 1$. For simplicity, assume that $T = 3$ and $R = \overline{w} < h_t$ for all $t \leq T$. Furthermore, assume that $\gamma = 1$ and $\delta = 1$.[22]

**Agent 1** faces the following intertemporal preference choice structure:

$$\left.\begin{aligned} u^1(w_1) &= F(\overline{w}) - C(\overline{w}) \\ u^1(w_2) &= F(\overline{w}) - 1 \cdot C(\overline{w}) \\ u^1(w_3) &= F(\overline{w}) - 1 \cdot C(\overline{w}) \end{aligned}\right\} \quad \therefore u^1(w_1) = u^1(w_2) = u^1(w_3)$$

$$\therefore \quad \boldsymbol{s_{Agent1}} \equiv (Y, -, -)$$

The result above shows that Agent 1 is completely indifferent between doing the task on day 1, day 2, or day 3. However, since Agent 1 has no incentive to procrastinate, as per the perception-based strategy, she chooses to perform the task on day 1 such that her total utility is given by:

$$U_{Agent1} = F(\overline{w}) - C(\overline{w})$$

**Agent 2** faces the following *intertemporal preference structure*:

$$\left.\begin{aligned} u^1(w_1) &= F(\overline{w}) - C(\overline{w}) \\ u^1(w_2) &= F(\overline{w}) - 0.5^0 \cdot C(\overline{w}) = F(\overline{w}) - 1 \cdot C(\overline{w}) \\ u^1(w_3) &= F(\overline{w}) - 0.5^0 \cdot C(\overline{w}) = F(\overline{w}) - 1 \cdot C(\overline{w}) \end{aligned}\right\} \quad \therefore u^1(w_1) = u^1(w_2) = u^1(w_3)$$

$$\therefore \quad \boldsymbol{s_{Agent2}} \equiv (Y, -, -)$$

[22] O'Donoghue and Rabin (1999:107) note that the assumption that $\delta = 1$ may be made purely for convenient simplicity as it does not affect the results from the model.

The result above shows that, because Agent 2 is *perfectly sophisticated*, his *conscientiousness* completely neutralises his present-biased preferences such that, given his perception-based strategy, he has no incentive to procrastinate. Therefore, Agent 2 effectively behaves exactly like an agent with time-consistent preferences, performing the task on day 1 and receiving total utility:

$$U_{Agent2} = F(\overline{w}) - C(\overline{w})$$

Finally, **Agent 3** faces the following *intertemporal preference structure*:

$$\left.\begin{aligned} u^1(w_1) &= F(\overline{w}) - C(\overline{w}) \\ u^1(w_2) &= F(\overline{w}) - 0.5^1 \cdot C(\overline{w}) = F(\overline{w}) - 0.5 \cdot C(\overline{w}) \\ u^1(w_3) &= F(\overline{w}) - 0.5^1 \cdot C(\overline{w}) = F(\overline{w}) - 0.5 \cdot C(\overline{w}) \end{aligned}\right\} \therefore u^1(w_1) < u^1(w_2) = u^1(w_3)$$

$$\left.\begin{aligned} u^2(w_2) &= F(\overline{w}) - C(\overline{w}) \\ u^2(w_3) &= F(\overline{w}) - 0.5^1 \cdot C(\overline{w}) = F(\overline{w}) - 0.5 \cdot C(\overline{w}) \end{aligned}\right\} \quad \therefore u^2(w_2) < u^2(w_3)$$

$$\left.\begin{aligned} u^3(w_3) &= F(\overline{w}) - C(\overline{w}) \\ u^3(w_4) &= 0 - 0.5 \cdot 0 = 0 \end{aligned}\right\} \quad \therefore u^3(w_3) > u^3(w_4)$$

$$\therefore \quad \boldsymbol{s_{Agent3}} \equiv (N, N, Y)$$

The analysis above differs quite markedly from the cases for Agent 1 and Agent 2. On day 1, Agent 3's *complete naivety* and her present-biased preferences lead her to expect that she will be better off if she works on the task either on day 2 or day 3 rather than on day 1. Therefore, she procrastinates on day 1. On day 2 however, she expects to be better off if she works on the task on day 3 rather than day 2, so she also procrastinates on day 2. On day 3, Agent 3 faces a new problem. She is aware that, even if she worked on the task on day 4, she would get no reward since it would then already be past the task deadline. However, since the reward incentivises the input of labour into the performance of the task, she would therefore also not be willing to perform any work on the task on day 4. As a result, Agent 3 chooses to work on the task on day 3 for which she receives utility:

$$U_{Agent3} = F(\overline{w}) - C(\overline{w})$$

A couple of important results flow from the analysis above. Firstly, *Perfect Sophisticates* with present-biased preferences will always behave as if they had time-consistent preferences. That is, they will have no incentive to procrastinate and will subsequently maximise their own subjective utility. Secondly, *Perfect Naïfs* with present-biased preferences will always have an incentive to procrastinate at least until time $t = T$. In the example above, Agent 3 was able to procrastinate until the last day and still maximise her own subjective utility as per lemma 1. However, it should be clear that this would not have been the case if $R > h_t$ for all $t \leq T$. Under these circumstances, procrastinating until day 3 would have meant that Agent 3 would not be able to complete $R$ hours of work before the deadline and, consequently, that she would only be able to receive a reward equal to $F(w_T) < F(R) = F_G$. According to lemma 2, Agent 3's procrastination would then have lead to a loss relative to her maximum subjective utility:

$$U(R) - U(w_T) = F(R) - C(R) - [F(w_T) - C(w_T)] > 0$$

This finding characterises the third and perhaps most important result from this model: Procrastination leads to the non-maximisation of total subjective utility when it causes agents to perform too little work on a task to achieve their own, subjective, predetermine goals. This result is illustrated more clearly in the next section.

## 5. Welfare Implications of Procrastination: Illustrative Examples

This section employs the model of procrastination developed above to analyse two illustrative examples of the welfare implications of procrastination for different levels of *conscientiousness*. To this end, recall the representative agent, Sarah, from Section 4.1 above. Suppose that Sarah is one of three triplets. Sarah and her two brothers, Dev and Don, are all three enrolled in a postgraduate Microeconomics course at University. As partial fulfilment of the course's requirements, all students have to write a short academic paper on behavioural economics. Their lecturer has given them 10 days to complete and hand in this assignment for grading. For the purposes of simplification, assume that the lecturer grades papers according to the amount of time that students

put into writing them and that the students are aware of the lecturer's specific approach to grading papers.

Assume that the triplets are identical in every conceivable way, save for their levels of *conscientiousness*. Sarah is *partially sophisticated* and has an $\alpha$ equal to 0.5. Dev is slightly *more conscientious* than Sarah such that his $\alpha$ is equal to 0.4. Don is the *least conscientious* with an $\alpha$ equal to 0.6. The triplets are accustomed to doing quite well academically and would ideally each like to receive score of 80 out of a possible 100 for their academic papers. To do so in reality, they would each need to work 40 hours in total before the deadline. However, the triplets all have present-biased preferences and therefore have at least some incentive to procrastinate. Assume that their $\beta$s are all equal to 0.5. Finally, as in Section4, assume for simplicity that $\delta = \gamma = 1$.

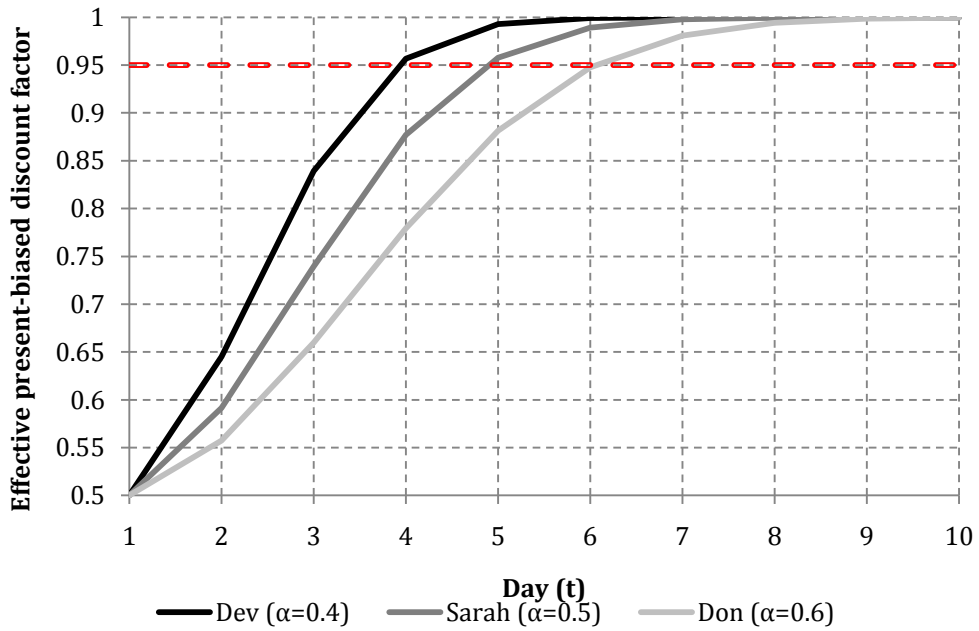
## 5.1. Case 1: No Uncertainty

Assume that the triplets correctly anticipate that they will need to work $\sum_{t=1}^{10} w_t = 40 = R$ hours in order to receive their goal reward $F_G = 80 = F(R)$. Furthermore, assume that, because of various other constraints on their time during the 10 days, they will only be able to work on the paper for a maximum of 8 hours each day. That is, $h_t = 8$ for all $t \leq T$ such that $\sum_{t=1}^{10} h_t = 80$. Lastly, assume that the triplets not only know that they have 80 hours in total to do the work they need to do, but also that they have only 8 hours available each day.

To determine how they should structure their labour over the course of the 10 days, the triplets each follow their own perception-based strategy. The effective present-biased discount factors (hereafter $\beta_{effective}$) that inform these strategies are shown in Figure 2 below. [23]

[23] As an example of how the model functions, the calculation of Sarah's effective present-bias discount factors is shown in the appendix.

*Figure 2 - Sarah, Dev, and Don's effective present-biased discount factors without uncertainty*




To calculate the triplets' respective intertemporal-preference structures, it is first necessary to define a threshold $\beta_{effective}$ above which agents will become indifferent between working on day $t$ and day $t+1$ for all $t \leq T$.[24] It should be evident that this threshold $\beta_{effective}$ is not only necessary for the model to yield predictions of behaviour, but also that it critically influences the nature of those predictions. Unfortunately, in the absence of any empirical estimates regarding agents' sensitivities to temporal saliency differences, the choice of this threshold value is somewhat idiosyncratic and is anchored only by notion that agents will work "*...if and only if* $u^t(w_t) \gtrsim u^t(w_\tau)$..." as stated in Section 4.5 above.[25] For the purpose of this paper, the threshold is assumed to be $\beta_{effective} = 0.95$. Given this threshold, Sarah, Dev, and Don's intertemporal labour decision structures can be estimated as in Table 1 below.

[24] Of course, on day $t = T$, agents will likely not be indifferent between working on day $T$ and on day $T+1$, since working on day $T+1$ no longer brings any reward. Instead, agents would prefer to work on day $T$ and receive reward $F < F_G$ if $F$ is sufficiently large to offset the cost of labour performed to obtain it.

[25] The problem here is that one cannot definitively state when $\beta_{effective}$ may be regarded as equivalent to 1. One could assume that the true threshold $\beta_{effective}$ would lie closer to 1 for agents who are more sensitive to saliency differences than for agents who are less sensitive to such differences. However, in the absence of any definitive knowledge regarding agents' levels of sensitivity, it may be prudent to choose a universal threshold and apply it to all agents under consideration.

*Table 1 - Sarah, Dev, and Don's intertemporal labour decision structures without uncertainty*

| | **Day (t)** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Available** | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | **80** |
| **Hours Worked** | **Dev** ($\boldsymbol{\alpha = 0.4}$) | - | - | - | 8 | 8 | 8 | 8 | 8 | - | - | **40** |
| | **Sarah** ($\boldsymbol{\alpha = 0.5}$) | - | - | - | - | 8 | 8 | 8 | 8 | 8 | - | **40** |
| | **Don** ($\boldsymbol{\alpha = 0.6}$) | - | - | - | - | - | - | 8 | 8 | 8 | 8 | **32** |

Consider first the case of Sarah whose perception-based strategy is given as: $\boldsymbol{s}_{Sarah} \equiv (N, N, N, N, Y, Y, Y, Y, Y, -)$. Sarah thus procrastinates for the first four days, but during the remainder of the time before the deadline, she works eight hours a day for five days. In total, therefore, Sarah works the 40 hours necessary to achieve the grade that she aimed for. As a result, despite procrastinating, Sarah maximises her own total subjective utility as per lemma 1:

$$U_{Sarah} = F(R) - C(R)$$

Now consider Dev's perception-based strategy: $\boldsymbol{s}_{Dev} \equiv (N, N, N, Y, Y, Y, Y, Y, -, -)$. Since Dev is *more conscientious* than Sarah, he procrastinates one day less before starting work on his paper. As a result, Dev finishes his paper one day before Sarah finishes hers and also maximises his own total subjective utility:

$$U_{Dev} = F(R) - C(R)$$

Finally, Don's perception-based strategy is given as: $\boldsymbol{s}_{Don} \equiv (N, N, N, N, N, N, Y, Y, Y, Y)$. Don procrastinates two days longer than Sarah, and 3 days longer than Dev. Unfortunately, because Don procrastinates for so long, he is only able to work on the paper during the last four days before the deadline. In other words, Don realises too late that his procrastinating behaviour will impede his ability to complete the task as he initially intended. As a result, he can only do 32 hours of work in total, not the 40 hours which he would have preferred. According to lemma 2 this implies that Don suffers a loss relative to his optimal total subjective utility:

$$U_{Don} = F(32) - C(32) < F(R) - C(R)$$

This example illustrates how agents' levels of *conscientiousness* may impact on the extent to which they procrastinate. From the results above, it appears as though agents

who are sufficiently *sophisticated* may be able to perform a task as satisfactorily (with no loss of personal welfare) as agents who do not procrastinate at all. Similarly, the more *naive* agents are, the more it seems they will be unable to overcome their self-control problems such that the impact of their procrastination on their personal welfare could indeed be negative. However, in this example it was assumed that the agents under consideration were capable of correctly anticipating the number of hours that they would have to work in total to achieve their goals and that they knew not only how many hours they had available to do this work, but also how these hours were spread across time. The example in the next section relaxes these assumptions to see how uncertainty affects the extent and welfare implications of procrastination.

## 5.2. Case 2: Facing Uncertainty

Suppose that, instead of the triplets correctly estimating the amount of time they would have to work on the paper to get 80 out of 100, they underestimate the value of $R$ to be equal to 30 hours.[26] Also suppose that the triplets believe that they have a total of 100 hours over the 10 days in which to complete the task. Furthermore, assume that they are unaware that, in reality, the 80 hours available to them are spread randomly across the 10 days such that: $h_1 = 8;\ h_2 = 6;\ h_3 = 13;\ h_4 = 12;\ h_5 = 3;\ h_6 = 5;\ h_7 = 8;\ h_8 = 5;\ h_9 = 7;\ h_{10} = 13$. Finally, assume that the triplets will only gain knowledge of the true values of $R = 40$ and $\sum_{t=1}^{10} h_t = 80$ once they begin work on their papers. All other details remain as in Section 5.1 above. The new effective present-biased discount factors and intertemporal labour decision structures are shown in Figure 3 and Table 2 respectively.

[26] This could happen if the triplets were under the impression that they knew quite a lot about behaviour economics and, subsequently, that it would not take them that long to write a really good paper on it.

*Figure 3- Sarah, Dev, and Don's effective present-biased discount factors with uncertainty*

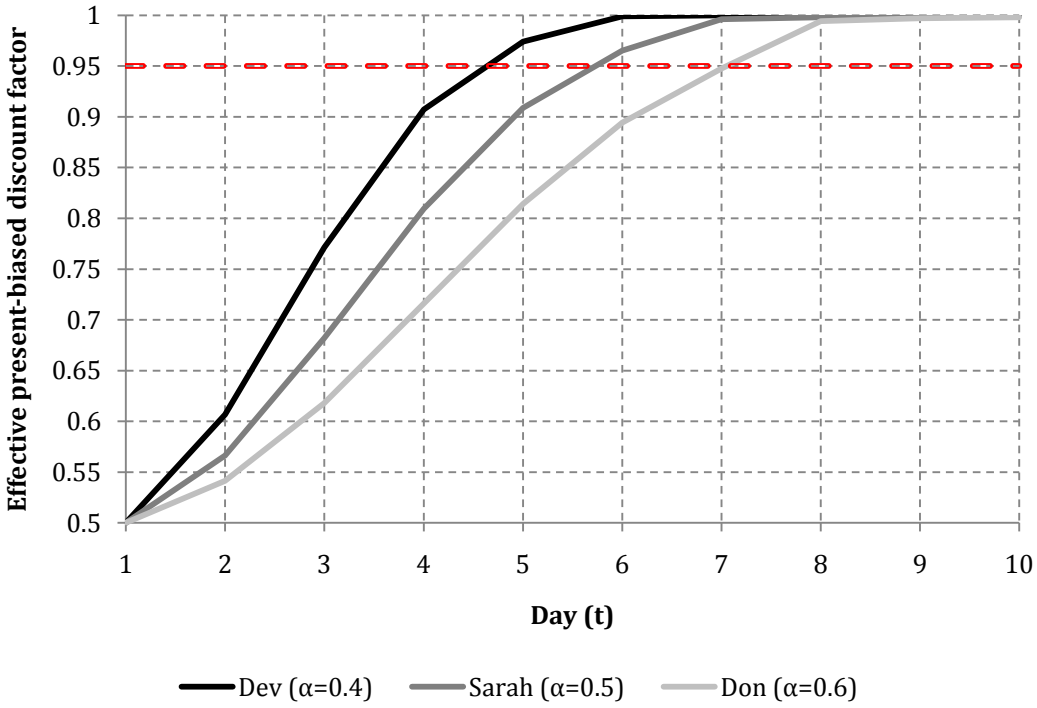



*Table 2 - Sarah, Dev, and Don's intertemporal labour decision structures with uncertainty*

| | **Day (t)** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Available** | 8 | 6 | 13 | 12 | 3 | 5 | 8 | 5 | 7 | 13 | **80** |
| **Hours Worked** | **Dev** ($\boldsymbol{\alpha = 0.4}$) | - | - | - | - | 3 | 5 | 8 | 5 | 7 | 12 | **40** |
| | **Sarah** ($\boldsymbol{\alpha = 0.5}$) | - | - | - | - | - | 5 | 8 | 5 | 7 | 13 | **38** |
| | **Don** ($\boldsymbol{\alpha = 0.6}$) | - | - | - | - | - | - | - | 5 | 7 | 13 | **25** |

Sarah's new perception-based strategy is: $\boldsymbol{s}_{Sarah} \equiv (N, N, N, N, N, Y, Y, Y, Y, Y)$. The change in Sarah's strategy relative to her strategy in Section 5.1 comes from two sources. Firstly, Sarah underestimates the amount of work (time) it will take to complete her paper in a satisfactory manner and overestimates the time at her disposal to do so, causing her to procrastinate another day. Secondly, even though she updates her expectations to the correct values of $R$ and $\sum_{t=1}^{10} h_t$ once she starts working on the task, the fact that she could not foresee how the available time was structured over the remaining days means that she can only complete a total of 38 hours work before the deadline. Thus, while Sarah's procrastination did not affect her total subjective utility

when she did not face uncertainty as in Section 5.1, the uncertainty here resulted in her procrastination causing a direct loss of personal welfare:

$$U_{Sarah} = F(38) - C(38) < F(R) - C(R)$$

Dev's perception-based strategy under uncertainty is given by: $\boldsymbol{s}_{Dev} \equiv (N, N, N, N, Y, Y, Y, Y, Y, Y)$. The same factors that influenced the changes in Sarah's strategy between certainty and uncertainty are also responsible for changing Dev's perception-based strategy. While Dev procrastinated only one more day under uncertainty than under certainty, the structure of the remaining available labour time meant that he only just finished his paper (i.e. a total of 40 hours of work) on the day before the deadline instead of two days before the deadline. However, Dev's level of *conscientiousness* was sufficient to counteract any negative implications that uncertainty (in this example) may have had for his personal welfare and he was therefore still able to maximise his total subjective utility:

$$U_{Dev} = F(R) - C(R)$$

Don, the *least sophisticated* of the triplets, procrastinated one day longer when he possessed uncertain knowledge regarding the task characteristics, as is shown by his perception-based strategy: $\boldsymbol{s}_{Don} \equiv (N, N, N, N, N, N, N, Y, Y, Y)$. As a result, his procrastination resulted in an even greater loss of welfare than it had when there was no uncertainty:

$$U_{Don} = F(25) - C(25) < F(32) - C(32) < F(R) - C(R)$$

The findings from this example illustrate that increased uncertainty regarding the true values of the task parameters increases the likelihood that agents will procrastinate more severely, that such procrastination will result in a loss of personal welfare, and that the extent of this welfare loss will be greater than under certainty. However, it is also clear that *less conscientious* agents are much more susceptible to the negative impacts of uncertainty than *more conscientious* agents.

## 6. The New Model of Procrastination: Some Limitations

The model presented in Section 4 and illustrated in Section 5 above provides some insights into the theoretical role that present-biased preferences and *conscientiousness* play in informing procrastinating behaviour. However, its cumbersome functional form and its dependency on, and sensitivity to, subjective judgements of threshold levels of saliency impede its analytic tractability. Moreover, there are several aspects surrounding procrastination that it fails to address. The first and foremost of these is the fact that the amount of time spent on the performance of a task is not necessarily the same as the amount of effort put into its performance. Not only do different agents possess different productive capacities, but agents may also be more productive under certain circumstances than others. In fact, it is commonly held that some agents are more productive under pressure, while others are more productive when they have ample time in which to perform a task. For certain agents, procrastination may thus actually be beneficial if it implies that less time has to be spent on the performance of a task when that task is performed closer to the deadline. (Tice and Baumeister, 1997:455)

The illustration of the model in Section 5 also ignores the importance that the saliency of rewards plays in incentivising procrastination. When the nature and timing of rewards are clearly defined, agents have a clear goal to work towards. In a sense, the clarity with which rewards are defined reduces uncertainty surrounding task characteristics and requirements, thereby reducing the incentive to procrastinate (Fischer, 2001:256). By contrast, when rewards and the timing thereof are vaguely defined, they may be *unduly* discounted, making the present costs even more salient in relation to the rewards. This is often the case with academic procrastination. Students may, for example, not always know precisely what the reward from writing an academic paper is supposed to be. Is it the grade to be obtained for the paper; is it the knowledge obtained from writing the paper; or is it the fact that, by completing the paper, students regain the *time* to do the things that they actually want to do? In the absence of clear answers to such questions, agents may discount the value of rewards more heavily than the costs incurred to attain them.

Another factor not addressed in the model is that serious procrastination, to the extent that it renders an agent unable to satisfactorily perform a task, may lead to the imposition of serious penalties. Consider, for example, an agent employed at an investment management firm who is assigned a certain high-priority task. Satisfactory completion of the task may bring the reward of a job-promotion. However, unsatisfactory completion of the task as a result of too much procrastination may not only mean that the agent does not receive this promotion, but that, instead, the agent is actually demoted. In this sense, rewards and penalties operate as the *carrots* and *sticks* that provide the incentive to perform a task in a timely manner. (Fischer, 2001:260)

The model in Section 4 implicitly assumes that procrastinating individuals will always have an incentive to begin work on the task no later than on the day before the deadline. However, within the context of the rewards and penalties of a task, it is conceivable that serious procrastination may increase the risk of abandoning the performance of a task altogether. That is, for many agents, there is likely to be some threshold level of input, below which the rewards they will receive in exchange for the performance of a task no longer justifies the costs they have to incur to perform it. Similarly, if the penalties expected from performing less than this threshold level of input are trivially different from the penalties expected from not doing any work, the agent may have an incentive to abandon the task. (O'Donoghue and Rabin, 2008:162)

Thus far, it has been assumed that the time available for the performance of a task is structured in a fixed manner across the number of days before the task-deadline. In reality, however, agents may restructure this available time as they choose.[27] When procrastinating agents realise close to the deadline that they cannot possibly finish the task satisfactorily given the constraints imposed on their time by other responsibilities, they may abandon some of these other responsibilities in an attempt to increase the time they have available for the performance of the task. However, it is quite possible that such tradeoffs may be costly to an agent. Specifically, while this paper considered task procrastination somewhat in isolation by arguing that procrastinating behaviour

[27] Of course, this is not to say that the choice to restructure ones responsibilities and/or available time is not constrained.

only results in a loss of welfare if it impedes the satisfactory completion of the task being procrastinated on, procrastination on one task may also impede the satisfactory completion of other tasks which compete for the agent's time. Thus, if agents respond to procrastination by re-allocating time between competing tasks near the deadline, it is quite possible that, by shifting the costs of task performance, their procrastinating behaviour would result in losses to personal welfare similar to, albeit for different reasons, than what is suggested in Sections 4 and 5.

Finally, the analysis in this paper disregards any adverse effects that procrastination may have on the emotional or physical wellbeing of the procrastinating individual. However, evidence from the psychological literature shows that procrastinating behaviour is often associated with considerable feelings of regret, anxiety or dejection (Tice and Baumeister, 1997:454). In turn, the stress brought about by procrastination may not only impede the performance of the task in question, but may in some case even have detrimental impacts on an agent's health (Tice and Baumeister, 1997:457). Therefore, to accurately determine the welfare implications of procrastination it becomes necessary to look at the extent to which procrastinating behaviour is self-defeating not only in terms of impeding an agent's ability to satisfactorily complete a task, but also in terms of reducing an agent's physical and emotional wellbeing.

## 7. Conclusion

Procrastinating behaviour is a phenomenon that manifests in practically all aspects of human endeavour. Despite its pervasiveness, however, surprisingly little is still understood about the implications that it may have for both personal and social welfare. In this paper, an attempt was made to provide an overview of procrastination, its causes and consequences, and its relevance to the field of economics. Given the evidence from both the psychological and economic literatures, it is clear that procrastination can best be explained as a result of present-biased preferences which are formed in response to the differential saliency (from both a temporal and spatial perspective) of costs relative to rewards. In this context this paper has argued that, although the underlying preferences that incentivise procrastination are dynamically inconsistent and therefore irrational, procrastination is a rational response to these present-biased preferences.

One of the shortcomings of previous models of intertemporal preferences that have been used to analyse procrastination is that they fail to explain how marginal changes in an agent's degree of *conscientiousness* regarding personal expected self-control problems and the nature and requirements of tasks influence the extent of procrastinating behaviour and, consequently, influence the welfare implications of procrastination. The new model proposed in this paper therefore parameterises an agent's degree of *sophistication* as an evolutionary process that transforms present-biased preferences into time-consistent preferences as the task deadline approaches.

The results from this model show that, for divisible tasks with immediate costs and delayed rewards, *more sophisticated* agents have an incentive to procrastinate less than their *more naive* counterparts. As a result, procrastination results in greater losses to personal subjective utility when agents are *less conscientious*. This effect is exacerbated when there is a larger degree of uncertainty regarding the nature and requirements of the task with which an agent is faced. However since the model ignores many of the subtleties related to real-world procrastinating behaviour, as discussed in Section 6, there are several reasons to believe that it may still underestimate the negative implications of procrastination on personal welfare.

The theoretical assertion that procrastination is costly to personal welfare is consistent with the findings of other behavioural models of procrastination and the experimental economic literature.[28] Acknowledging these potential costs of procrastination, it now becomes important to understand the extent to which individuals are *conscientious* in reality. Since there is evidence to suggest that the majority of chronic procrastinators exhibit greater *naivety* than *sophistication*, further research should examine how self-imposed and externally imposed self-control mechanisms, such as pre-commitment to intermediate deadlines or continuous assessment, can increase agents' levels of *conscientiousness* and subsequently reduce procrastinating behaviour. (Ariely and Werntenbroch, 2002:224)

[28] See O'Donoghue and Rabin (1999, 2001 and 2006), Fischer (1999 and 2001), Asheim (2008), Ariely and Werntenbroch (2002), Solomon and Rothblum (1984) and Bisin and Hyndman (2009).

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## APPENDIX:

Calculation of Sarah's effective present-bias discount factors:

| Time | Effective present-bias discount factor |
|---|---|
| t=1 | $0.5^{0.5\left\lfloor \frac{1(1-1)}{\frac{\left(0.5+1\times10^{-10}\right)0.5}{10-(40-0)/8}} \right\rfloor} = 0.5^{0.5^{0}} = 0.5^{1} = 0.5$ |
| t=2 | $0.5^{0.5\left\lfloor \frac{2(2-1)}{\frac{\left(0.5+1\times10^{-10}\right)0.5}{10-(40-0)/8}} \right\rfloor} = 0.5^{0.5^{0.26667}} = 0.5^{0.831237896} = 0.5602047$ |
| t=3 | $0.5^{0.5\left\lfloor \frac{3(3-1)}{\frac{\left(0.5+1\times10^{-10}\right)0.5}{10-(40-0)/8}} \right\rfloor} = 0.5^{0.5^{0.8}} = 0.5^{0.574349178} = 0.671589$ |
| t=4 | $0.5^{0.5\left\lfloor \frac{4(4-1)}{\frac{\left(0.5+1\times10^{-10}\right)0.5}{10-(40-0)/8}} \right\rfloor} = 0.5^{0.5^{1.6}} = 0.5^{0.329876978} = 0.795604$ |
| t=5 | $0.5^{0.5\left\lfloor \frac{5(5-1)}{\frac{\left(0.5+1\times10^{-10}\right)0.5}{10-(40-0)/8}} \right\rfloor} = 0.5^{0.5^{2.66667}} = 0.5^{0.157490131} = 0.896584$ |
| t=6 | $0.5^{0.5\left\lfloor \frac{6(6-1)}{\frac{\left(0.5+1\times10^{-10}\right)0.5}{10-(40-0)/8}} \right\rfloor} = 0.5^{0.5^{4.0}} = 0.5^{0.0625} = 0.957603$ |
| t=7 | $0.5^{0.5\left\lfloor \frac{6(6-1)}{\frac{\left(0.5+1\times10^{-10}\right)0.5}{10-(40-8)/8}} \right\rfloor} = 0.5^{0.5^{4.94118}} = 0.5^{0.0325505} = 0.97769$ |
| t=8 | $0.5^{0.5\left\lfloor \frac{6(6-1)}{\frac{\left(0.5+1\times10^{-10}\right)0.5}{10-(40-16)/8}} \right\rfloor} = 0.5^{0.5^{5.89474}} = 0.5^{0.016807665} = 0.988417$ |
| t=9 | $0.5^{0.5\left\lfloor \frac{6(6-1)}{\frac{\left(0.5+1\times10^{-10}\right)0.5}{10-(40-24)/8}} \right\rfloor} = 0.5^{0.5^{6.85714}} = 0.5^{0.008625699} = 0.994039$ |
| t=10 | $0.5^{0.5\left\lfloor \frac{6(6-1)}{\frac{\left(0.5+1\times10^{-10}\right)0.5}{10-(40-32)/8}} \right\rfloor} = 0.5^{0.5^{7.82609}} = 0.5^{0.00440670} = 0.99695$ |