# Aspiration, Inspiration and Perspiration: A Model of Dynamic Project Choice

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**Abstract**

Progress results either from diligent, time-consuming work or from creative inspiration. Consider an agent looking for a solution to a problem while facing a deadline. The agent dynamically decides whether to look on the diligent road or on the creative road. Progress arrives stochastically and the diligent road leads to a solution eventually. The creative road is quicker, but sometimes infeasible. Looking on the creative road provides information about its feasibility. Optimal choices are non-monotone. The agent focuses on creative work if the deadline is soon or far. He concentrates on diligent work for intermediate time remaining.

A principal who cares about both screening and output offers one of two contracts: (i) A short deadline and tenure for creative solutions, or (ii) instant tenure and promotion for all creative and some diligent solutions. Our applications are academic careers, election cycles and policy reforms, and product innovation.

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I shall be telling this with a sigh
Somewhere ages and ages hence:
Two roads diverged in a wood, and I—
I took the one less traveled by,
And that has made all the difference.

*Robert Frost—The Road Not Taken*

# 1 Introduction

A common interpretation of the last stanza of Frost's poem is that it promotes the use of new and creative approaches. Creativity and the desire to go new, untraveled roads appears often as the career-making step in people's life. While the creative, less-traveled-by road may offer a shortcut out of the woods, it may also lead to a dead end. The more-traveled-by road, in turn, is sure to deliver a way out of the wood. Yet, that way out may be very long and winding.

In this paper we consider an agent that dynamically chooses between two roads while facing a deadline. At each instance he can either choose to go an untraveled, creative road or to go the well-known road of execution. Execution leads to a solution eventually, but requires diligence as progress is stochastic. Creativity, in turn, is fundamentally risky. It may have no chance of progress at all, yet if it does, it promises a shorter, direct path towards the solution.

We solve the agent's dynamic choice problem given the time that remains until the deadline. We investigate how the contractual environment interacts with the agent's choices. We consider a principal that desires solutions and prefers creative ones, but observes the road taken imperfectly. Finally, we analyze the trade-off between productivity and creativity in light of a given deadline.

We take a continuous-time experimentation model in which an agent can—at any point in time—decide to work on a creative task or a diligent task. Working is costly and progress is stochastic. The probability of progress on the diligent task is independent of the state of the world. However, whether a creative solution exists depends on the state of the world. A solution through the diligent task requires several steps while the creative solution is one-step only. At the deadline, the principal observes whether the agent has found a solution and some of its characteristics. She then decides whether or not to promote the agent.

Our framework applies to various principal-agent problems. We have three specific areas in mind.

**Academia.** Following the "publish or perish" paradigm, standard tenure-track positions typically have a fixed tenure clock. After the clock runs out, the promotion-and-tenure committee decides upon tenure. The committee wants to award tenure to a creative mind only and bases its decision on hard requirements; that is, the publications needed, and on letters written by academic experts. In our model fulfilling the requirements corresponds to a solution. The letters serve as an imperfect measure of the solution's characteristics. Ideally, the letters determine whether the candidate's contribution is original and creative or a straight-forward execution of a set of known concepts from the literature.

**Polity.** Evaluation of governments in democracies occurs in fixed election cycles. After each political cycle voters decide whether to reelect the government based on the government's performance. Voters want to reelect only those politicians that provide a sustainable reform to overcome the problems in the society. Voters can observe if the government successfully implemented a reform. However, they only imperfectly observe the long-run effects of that reform and thus are uncertain whether the reform is sustainable or not.

**Industry R&D.** Consider a production company that employs a worker for her R&D division. If the worker is successful within a certain time-frame to launch a new product he can apply for promotion. The employer can observe whether a worker developed a product. Yet, she only imperfectly sees whether the product is sufficiently innovative to provide the company with additional earnings.

We identify a non-monotone relationship between the agent's choice of task and the remaining time until the deadline. If the deadline is far away, an optimistic agent will first attempt to find a creative solution. As time passes without finding the solution, the agent becomes more pessimistic about the state of the world. He switches to the diligent task to insure himself against failure. Yet, the likelihood of completing the diligent work on time shrinks quickly. Without progress the agent prefers to gamble on finding a creative solution despite his pessimism once the deadline is near.

The result highlights the dynamic tradeoff between learning and progress. We provide two benchmarks to build intuition. In the first benchmark, we eliminate the time pressure and study the agent's optimal policy without deadline. We find that the agent initially works on the creative task when still optimistic because this allows him to save on effort in case the creative solution exists. After some time without a creative solution the agent is too pessimistic to continue searching for a creative solution and switches to the diligent task on which he eventually succeeds. In the second benchmark, we eliminate the effort cost advantage of the creative task and study the agent's optimal policy with zero effort cost but finite deadline. We find that the agent start searching for a solution on the diligent road. However, if no progress has been made sufficiently far from the deadline, the agent gives up on the diligent road and attempts finding a creative solution.

These findings highlight the advantages of the creative task: (i) if a creative solution exists, it allows the agent to save on effort, (ii) if little time remains, the creative task has, in contrast to the diligent approach, a reasonable chance of succeeding. However, the creative approach is fundamentally risky and potentially never yields a solution and when working without finding a creative solution increases the agent's pessimism about the existence of a creative solution.

Solving the full problem with a positive cost of effort and a finite deadline, we find a non-monotone optimal policy of the agent: At the beginning, the agent is optimistic to find a creative, direct solution. Finding a creative solution early on saves the agent cost of effort. As time progresses without progress the effort he expects to save decreases. In addition, he becomes more pessimistic about the feasibility of a creative solution. At the same time, the probability of finding *some* solution declines because the deadline approaches. In response, the agent switches with sufficient time remaining. However, close to the deadline he attributes a low likelihood to succeeding at all, if he did not make progress yet. Although genuinely pessimistic, he decides to "throw a Hail Mary." He hopes to find a creative solution last minute rather than running out of time on the diligent task.

In a second step, we analyze how the agent's decision problem interacts with the incompleteness of the contracting space. We assume that the agent's choices are non-verifiable. Instead approval of creative solutions is more likely than approval of diligent solutions. We show that this setting implies a non-monotone relationship between the likelihood of creative solutions and the length of the deadline.

For short deadlines, a solution is not likely. Yet, any solution is creative. Intermediate deadlines make a solution likely but diligent solutions crowd out the creative ones. Long deadlines on the other hand almost guarantee a solution which may be the result of either, the creative or the diligent task.

Our results provide testable implications for each of our three examples above.

**Academia.** According to our model, researchers on tenure tracks should seek to produce original work at early stages of their career. If they fail to progress, they switch focus to execution rather than originality. Researchers without significant output who are close to evaluation offer more originality again.

Short term contracts such as post-docs should deliver a high level of originality. Yet, we also expect many that do not produce anything under these contracts. Medium-term tenure clocks should deliver more output, but less originality. Long tenure clocks increase the share of researchers producing high-originality work compared to medium term clocks. However, different to short-term contracts those that do not produce original work, produce other work instead.

**Polity.** Our model suggests that politicians undertake structural reforms either right after election or shortly before reelection. Mid-term they are more likely to offer policies targeting short-run goals. Short election cycles incentivize structural reforms, but bear a high risk of deadlocks. Intermediate cycles improve the likelihood of seeing some reforms, but most of the reforms are only short sighted. Finally, long election cycles guarantee some reforms and foster structural reforms early in the cycle. Failing to provide such a reform then implies that short-sighted reforms become more likely.

**Industry R&D.** Pressing workers to invent new products in a short time span leads either to failure or the development of innovative new products. Extending the time for the R&D staff leads to more inventions, but fewer with chances of long-run success. If the time frame is very large, workers invent new products almost surely. Long-run success is possible, but not guaranteed.

In the last part of the paper we address a principal's *trade-off between inducing effort and screening* the agent's type. The principal prefers a creative solution over a diligent solution over no solution. We measure the principal's desire to screen as the ratio of her payoffs under a creative solution over those under a diligent solution.

Consider a principal that can pick the probability of approval[1] for a diligent success at no cost. Given a long enough deadline, the principal never desires to disapprove all diligent solutions if she prefers a diligent solution over no solution at all. Moreover, the optimal approval rate is higher than the inverse of the principal's desire to screen: The principal approves diligent solutions sometimes to motivate the agent to work even when pessimistic. She picks a higher approval rate than the inverse of her desire to screen – thereby overcompensating the agent relative to her preference for diligent progress due to the higher effort cost of the agent on the diligent road.

Now consider a principal that can set a deadline no cost. Given a probability of approval, the optimal deadline is either short enough such that the agent works on the creative solution throughout or arbitrarily long. The former implies the highest

[1]Choosing the probability of approval is equivalent to choosing a lower payment for diligent solutions than for creative ones.

screening value, the latter guarantees a solution almost surely. The principal always prefers one of the two over any other deadline.

A single threshold on the desire to screen determines the principal's optimal choice. If her desire to screen is larger than this threshold, she is willing to forgo on solutions to incentivize the agent to work on the creative path. If her desire to screen is smaller, she is willing to forgo on some screening potential to make sure the agent obtains some solution.

Combining the two partial results implies that one of the following two contracts is optimal: either (i) a tenure-track system with tenure for a creative solution, or (ii) instant tenure with a promotion awarded with certainty for creative solutions and randomly for diligent solutions. The principal offers a tenure-track if her desire to screen is high, and immediate-tenure otherwise.

**Related Literature.** The literature on dynamic project selection is surprisingly small. In a recent paper Nikandrova and Pancs (2018) study the selection process between two mutually exclusive projects. Similar to our model, they use the single-agent version of a multi-armed bandit model (Bolton and Harris, 1999; Keller, Rady, and Cripps, 2005). The project selection itself is made once and for all, while experimentation only occurs regarding the learning procedure. In contrast, the aim of our paper is to understand how time-pressure, and learning opportunities interact, when project selection is reversible at any point in time.

Closer to our approach is Forand (2015) who studies a single-agent model of experimentation and project choice. Similar to our model, there are two risky projects and the agent can decide to work on either or none. However, the time horizon is infinite. Abandoning a project is irreversible, unless the agent pays some "maintenance cost" to keep the project on hold. Forand (2015) shows that the agent may experiment on the less promising project first, before abandoning it completely. Despite the reversed order monotonicity continues to hold in his model, since the agent never goes back to a previously discontinued project. We show that once time-pressure is included into the model, the values of projects may cross more than once.

A series of recent papers adds career concerns to models of experimentation (e.g. Bonatti and Hörner, 2017; Halac and Kremer, 2017; Thomas, 2018). Closest in that literature is Bonatti and Hörner (2017) who, in line with our model, consider an agent with limited time to achieve a certain goal when outcomes are observable, but effort is not. In their model, however, there is a single road to the solution. More specifically, only one type of agent is able to succeed. To the contrary, in our model *any* type of agent is able to succeed. However, for some, but not all types there may be multiple roads to the solution.

More fundamentally, our focus is different. In the tradition of Holmstörm (1999), Bonatti and Hörner (2017) focus on the signaling component of experimentation. Breakthroughs signal high-quality and are therefore rewarded via a promotion. Similar concerns are raised in Aghion and Jackson (2016) who study how an agent may avoid to take an action that allows him (and the principal) to learn his type, only to avoid dismissal. Our approach to the problem is different. Instead of caring about the agent's fundamental type, the principal wants the agent to provide output. Learning about the agent's type is thus only a secondary concern of the principal. From her point of view the agent's type is a partial substitute to the agent's effort. Thus, she rewards the agent even if she fails to prove her type. From the agent's perspective, we therefore face a *sorting* problem. A fully informed agent would correctly sort into a task. However, the interaction between beliefs and time-pressure lead her to switch between the different options.

From an ex-ante perspective, the principal expects the agent to engage in multiple tasks over the given time period. Different to Holmstrom and Milgrom (1991) agent's choices are not constant over time, but the agent *switches* between different tasks. In addition, there is a direct conflict between tasks in the sense of Dewatripont and Tirole (1999). The agent can only learn by working on the hard task. Their proposed solution to split the tasks between agents is, however, not feasible. An agent's type is idiosyncratic and ex-ante uncertain. Thus, separation can only occur *after* the agent went through the process of experimentation.

On a technical level, Klein (2016) studies a related model in which an agent can decide between two roads: Honest research, or cheating. Similar to our creative road a solution on the honest road may not exist, while progress when cheating is only a matter of time. The crucial difference to our model is that there is no differential effect of time when deciding on between the roads. Our model is identical *after* the first progress on the diligent task. Our diligent solution is not equivalent to cheating. Instead diligent solutions have a value per se, but are less direct. Thus, finding a diligent solution takes longer, adding an additional layer of dynamics to the model.

Finally, our model builds on the assumption that workers are offered contracts with backloaded incentives and limited monitoring. This assumption is in line with Wilson (1989) describing government agencies and Baker, Jensen, and Murphy (1988) who provide justification and empirical evidence for such contracts.

## 2 Model

The state of the world is unobserved and binary, $\theta \in \{0, 1\}$. At the beginning of the game $p_0 \in (0, 1)$ is the common belief that $\theta = 1$. Time is continuous and starts at $t = 0$.

There are two players, a principal ("she") and an agent ("he"). Both are risk neutral. The principal wants the agent to provide a solution to a problem. In principle, two solutions are possible. A *creative solution* and a *diligent solution.* At the end, the principal receives a payoff normalized to 1 from a creative solution, and $\alpha \leq 1$ from a diligent solution. At the beginning of the game, the principal publicly commits to a deadline $T \in [0, \infty)$ and an approval probability of the diligent solution, $\rho \in [\underline{\rho}, \overline{\rho}]$ with $0 \leq \underline{\rho} < \overline{\rho} \leq 1$.

At each instance of time the agent can exert at most one unit of effort and distribute it between working on a diligent solution or on a creative solution, where $a_t$ is the share of total effort devoted to work on the creative solution at time $t$. Effort is costly to the agent and has a flow cost of $c > 0$. Progress arrives stochastically with intensity rate $\lambda > 0$ in either of the two paths if $\theta = 1$. If $\theta = 0$ progress can only be obtained when working on the diligent solution. Hence, the creative path has intensity 0. The intensity on the diligent path remains at $\lambda$.

A solution is found if the agent makes progress either *(i) once on the creative path*, or *(ii) twice on the diligent path.*[2] The agent receives an exogenous payment $B$ if he provides a creative solution *or* if he provides an approved diligent solution. We assume that $\lambda B > 2c$.

## 3 Analysis

We proceed in steps. We start by analyzing the agent's problem and begin with the extreme cases $\rho = 1$, that is, the principal does not (or cannot) distinguish between the different solution types. Initially, we provide two benchmarks – (i) no deadline, and (ii) no effort cost – to build intuition for the agent's optimal policy, which we derive next. Thereafter, we consider the case in which $\rho = 0$, that is, the principal rewards only creative solutions. Finally, we address case with $\rho \in (0, 1)$. Finally, we address the principal's problem.

[2]While our modeling choice that the diligent road corresponds to obtaining two successes, this assumption is not necessary for our qualitative results. We require that the first progress on the diligent task does not immediately yield a solution and has a continuation value $V(\tau)$ that depends on the time remaining until the deadline, $\tau$. The characteristic feature of a diligent task is that once an approach is developed, it needs additional time to be executed.

## 3.1 Dynamic Project Choice: Any Solution Pays

For the sake of simplicity we ignore the agent's ability not to work if no solution has been found, i.e., the agent's option to shirk, and focus on the trade off between working on a diligent solution and working on a creative solution. While we ignore shirking by assumption at this point, we are going to verify ex-post that this assumption is indeed innocuous for $B$ large enough. We proceed as follows. We first set up the agent's problem. We derive some necessary conditions of the optimal policy, and characterize it fully thereafter. Finally, we discuss several properties of the optimal policy.

### The Agent's Problem

We first analyze the agent's optimal policy over time. We use backward induction to solve our problem. Because working is costly, whenever the agent has found a solution he stops working immediately. Therefore, we only focus on histories in which no solution has been found yet. The agent's belief about the state of the world is represented by his belief $p_t$ which has $p_t \leq p_0$ in the absence of a progress on the creative path.

Suppose the agent has made progress once in the diligent path and let $\tau \equiv T - t$ be the time remaining until the deadline. Because $\lambda B > c$ and $p_t < 1$, working on the diligent path is a dominant strategy for the agent. His expected continuation value is

$$V(\tau) := \int_0^\tau e^{-\lambda t}(\lambda B - c)dt = (B - \frac{c}{\lambda})(1 - e^{\lambda \tau}).$$

Finally, consider the case in which the agent has not made any progress yet. We analyze the agent's problem using the necessary conditions of optimal control and represent all terms using only the time remaining, $\tau$, and the current belief $p_t$. A detailed derivation of the respective terms is in the appendix. The Hamiltonian is

$$\mathcal{H}_\tau = (1 - a_t)\lambda V(\tau) + a_t p_t \lambda B - c + a_t \eta_\tau,$$

where $\eta_\tau$ is the co-state evolving according to

$$\frac{\partial \eta_\tau}{\partial \tau} = (1 - p_t)\left((1 - a_t)\lambda V(\tau) - c\right),$$

and $(1 - a_t)\lambda$ is the probability making progress on the diligent path given effort $(1 - a_t)$ being devoted to it and $a_t \lambda p_t$ is the probability of making progress on the creative path given effort $a_t$ being devoted to it and the belief about the state of the world being $\theta = 1$ being $p_t$. Progress on the diligent path triggers the continuation value $V(\tau)$ while progress on the creative path triggers the benefit of a solution $B$.

The belief about the state of the world changes according to the law of motion

$$\dot{p}_t = -\lambda p_t(1 - p_t)a_t.$$

Under the optimal policy, the agent works on a creative solution if the Hamiltonian is increasing in $a_t$ and on a diligent solution if it is decreasing. The policy function at any point in time can be represented by

$$\gamma_\tau = \lambda V(\tau) - p_t \lambda B - \eta_\tau, \tag{1}$$

which evolves according to

$$\frac{\partial \gamma_\tau}{\partial \tau} = (1 - 2p_t)c - (1 - p_t)\frac{\partial V(\tau)}{\partial \tau},$$

if the agent makes no progress in period $t$. The agent will work on the creative solution whenever $\gamma_\tau < 0$ and on the diligent solution whenever $\gamma_\tau > 0$. It is important to keep in mind, that the expected evolution of $\gamma$ is independent of the current action choice $a_t$.

**Two Benchmarks: $T \to \infty$ and $c = 0$**

To build intuition for the tradeoffs the agent faces when deciding between the creative and the diligent we start the analysis by deriving the optimal policy for the agent in two benchmarks: First, we study his optimal policy in the infinite horizon problem. Then, we study his optimal policy when the effort cost is zero. The due to the requirement of two successes, the diligent task is less attractive than the creative task for two reasons: (i) close to the deadline a diligent solution is very unlikely to be obtained when no progress has been made so far. The first benchmark allows us to shut down this channel; (ii) the expected cost of effort on the diligent road is higher. The second benchmark allows us to shut down this channel. However, the creative task inherits fundamental risk: it may not be feasible to solve the problem with a creative approach and the agent updates his beliefs about the creative solution's feasibility.

**No time pressure – $T \to \infty$.** When the time horizon is infinite, the agent does not fear the risk of being unable to solve the problem diligently. However, the creative approach nevertheless has the benefit that it may save on effort costs.

**Proposition 1.** *Suppose the time horizon is infinite, $T = \infty$. The agent either works first on the creative task and switches then to the diligent task or works on the diligent task exclusively. The agent starts with the creative task when he is sufficiently optimistic at time zero, $p_0 \geq \tilde{p} \geq \frac{1}{2}$.*

Proposition 1 shows that if the agent is sufficiently optimistic initially and the time horizon is infinite, he will start working on the creative task and eventually switches to the diligent task. After switching, he never returns to the creative task and a success on the diligent road is obtained almost surely. The agent follows the creative road first to save some effort cost. As he becomes too pessimistic, he gives up on the creative road and will eventually obtain a solution with diligent work as their is no time pressure.

**No effort cost – $c = 0$.** When the cost of effort is zero, the agent only cares about the probability of success but not about how much work is required to obtain it. Hence, the effort saving incentive of working on the creative task is not present in this benchmark compared to the previous one. Nevertheless, the agent has an incentive to work on the creative task: when he has not progressed on the diligent task and the deadline approaches, the probability of obtaining to successes shrinks to zero very quickly. The only remaining chance to obtain a solution in time is by throwing a Hail Mary and trying to obtain a creative solution.

**Proposition 2.** *Suppose the cost of effort is zero, $c = 0$. The agent either works on the creative task exclusively or starts with the diligent task and switches to the creative task when no progress has been made. The agent starts with the diligent task when the deadline is sufficiently long, $T \geq \tilde{T}$.*

Proposition 2 shows that even when the creative task does not save on effort cost the agent may choose it: when time pressure is too high, diligence is not a promising approach anymore, while a creative solution might still be feasible. In particular, in contrast to the previous benchmark, the agent backloads the creative work.

**Why and when to choose the creative task?** The previous benchmarks offer a first insight into why the agent may choose the creative task: (i) the creative task potentially saves some effort cost, because when a creative solution is feasible, it takes less time, in expectation, to be completed; (ii) when the deadline approaches and no progress has been made, only the creative road has a sufficiently high likelihood of yielding a solution.

The effort-saving incentive suggests that the agent should start with the creative task, while the deadline incentive suggests that the agent should work on the creative task in the end. In the general setup when $T < \infty$ and $c > 0$, both effects are present and the optimal allocation of effort is yet to be determined. In particular, frontloading reduces the value of creative work later as working on the creative task without a success increases the agent's pessimism.

**Optimal Policy – Necessary Conditions**

We start our analysis at time periods close to the deadline and backward induct to the beginning using a sequence of lemmas.

**Lemma 1** (Hail Mary.)**.** *Suppose the agent has not made any progress yet. Then there is a remaining time $\hat{\tau}$ such that the agent strictly prefers working on the creative solution over working on the diligent solution whenever $\tau < \hat{\tau}$.*

The proof, as all others not included in the main text, is relegated to the appendix. Intuitively, if the time remaining is little, the agent has no hope of solving the problem on the diligent path because it is unlikely that progress is made twice in such a short time period. Therefore, and independent of his belief at that point, the agent prefers to throw a "Hail Mary" over the diligent path when being close to the deadline. Despite being generally pessimistic he still gambles on being lucky.

Our next result shows that if $T$ is sufficiently large, the agent is expected to work on the diligent solution with positive probability.

**Lemma 2.** *For $T$ sufficiently large it is not optimal for the agent to focus entirely on the creative solution.*

The intuition behind this result is based on the observation that working on the creative solution is informative to the agent. Whenever he works on the creative solution without any progress he becomes less optimistic about the underlying state. If the agent works on the creative solution long enough without progress, his belief becomes arbitrary small.

As $T$ grows large a strategy in which the agent focuses entirely on the creative solution involves the potential to look for a creative solution under a extremely pessimistic belief about its feasibility.

If the agent instead decides to work on the diligent solution, feasibility is guaranteed and the only uncertainty is about the timing of progress. The value of working on the diligent solution is bounded from below, in particular, because the agent can choose at which time to allocate his effort on the diligent path. Moreover, working on the diligent solution does not affect the agent's optimism. Thus, there has to be some remaining time $\tau$ such that the agent prefers to work on the diligent solution switching to the Hail Mary strategy if time passes without any progress.

Combining Lemma 1 and 2 establishes that an agent does not prefer one path over the other universally. With little time $\tau$ remaining the agent always prefers the creative path conditional on no previous progress. If the deadline is long enough the agent prefers the diligent path at some time.

Yet, there is a third effect, that we have not discussed so far. A creative solution is—conditional on feasibility—cheaper than diligent solution as the agent only needs to make progress once. Thus a monotone strategy is not guaranteed.

Next, we derive necessary conditions for the optimal strategy. We begin with a result stating that the agent does not explore both paths simultaneously.

**Lemma 3.** *Generically, the agent is not indifferent.*

The key step to this result is that the agent's current action choice $a_t$ has no first-order effect on the policy function as seen in Equation (1). Instead, the policy function depends on the remaining time $\tau$ and the belief $p_t$.

Given $p_t$, a decrease in the remaining time $\tau$ makes the diligent path increasingly less attractive. The likelihood of making progress twice shrinks faster than that of a single progress on the creative path—a first order effect.

At the point of indifference, that effect may be offset by the effect on the agent's belief. Working on the creative path reduces the belief. However, that effect enters only through the agent's action $a_t$—a second order effect.

As time passes $\gamma_\tau$ changes non-constantly in $\tau$ regardless of the agent's choice. The agent is indifferent for no positive measure of time. The second-order effect of $a_t$ implies that $\gamma_\tau$ is (strictly) concave in $\tau$. Concavity, in turn, implies that the policy function has no interior minimum which delivers the next result.

**Lemma 4.** *The agent works on the creative solution in at most two disconnected intervals of time. The agent works on the diligent solution in at most one interval.*

Lemma 1 and 4 imply that the agent expects to follow one of the following policies conditional on no progress: (i) he works on the creative solution throughout, (ii) he works first on the diligent solution and, as $\tau$ becomes small, he switches to the creative solution, and (iii) he starts working on the creative solution when $\tau$ is large, switches to working on the diligent solution eventually, before switching back to working on the creative solution when $\tau$ becomes small.

We can now pin down the agent's choice among the the potential policies.

**Proposition 3** (Optimal Policy—Necessary Conditions)**.** *For $T$ sufficiently large and $p_0 > 1/2$ the agent's policy conditional on not making any progress is the following. First he works on the creative solution, then switches to work on the diligent solution, before returning to work on the creative solution shortly before the deadline.*

**Corollary 1.** *If $p_0 < 1/2$ the agent either works on the creative solution throughout, or starts by working on the diligent solution before switching to working on the creative solution when no progress is made after some time.*

To interpret the results of Proposition 3 and Corollary 1 consider the following static variation. A risk neutral agent decides whether to work to find a diligent solution or a creative solution. The creative solution delivers twice the surplus of the diligent solution, but materializes only with probability $p_0$. Then, the agent would be indifferent if and only if $p_0 = 1/2$.

Proposition 3 and Corollary 1 state that the same reasoning is true at the first instance of time in an infinite horizon model. The intuition behind that equivalence is the following. As the time horizon is infinite, time effects are irrelevant. The agent is certain to obtain $B$ at the end, but wonders about the cost of his action. He knows that the diligent solution is twice as expensive, but is guaranteed to exist. Thus, if the creative solution exists with probability smaller than $1/2$, it is not worth working on the creative solution. If the solution exists with probability larger than $1/2$, it is not worth working on the diligent solution, initially.

Using our previous results Lemma 1 to 4 then determines the optimal policy. If the deadline is short enough, the agent focuses entirely on the creative solution. The likelihood of making a progress once on the creative path is higher than that of making progress twice on the diligent path. If the deadline is further away, the agent has a higher chance of getting to a solution on the diligent path. He works on the diligent solution until the time remaining is too short.

Finally, if the deadline is far *and* the agent is optimistic he wants to start working on the creative solution to save on effort. As the deadline moves closer the agent becomes more pessimistic and at the same time the time to complete the diligent solution shrinks. The agent switches to the diligent path with sufficient amount of time left to complete the solution. Switching to the diligent path stops the agents learning and his belief remains constant.

A constant belief implies a particular option value in case the agent has to switch to the Hail Mary strategy. Thus, the agent decides to invest in a diligent solution until she draws the option to throw the Hail Mary.

**Optimal Policy – Characterization**

The optimal policy is unique up to measure 0 events. To characterize it, we solve a fix point problem of time periods $T = \tau_1 + \tau_2 + \tau_3$ for an agent that fails to make any progress. For any set of parameters $(p_0, B, \lambda, T)$, the 3-dimensional vector $(\tau_1, \tau_2, \tau_3) > 0$ corresponds to the time the agent spends on the creative path at the beginning ($\tau_1 \geq 0$), the time he spends on the diligent path thereafter ($\tau_2 \geq 0$), and the time the agent spends on the creative path in the end ($\tau_3 > 0$). All three objects are endogenously determined.[3]

As in the previous section we present a set of results that determine the solution to the fix point problem.

**Lemma 5** (Hail Mary.)**.** *The agent throws Hail Marys when the remaining time is* $\tau$ *if and only if*

$$p_{T-\tau} \geq q(\tau) := \frac{\lambda(V(\tau) + c\tau)}{\lambda V(\tau) + \lambda c\tau + c + V'(\tau)} \in (0, 1).$$

Lemma 5 fully determines the most pessimistic belief $q(\tau)$ such that the agent exclusively works on the creative solution when the remaining time is $\tau$. To determine the second interval we define the function $y$ via

$$\dot{y}(s; p, \tau, t) := \lambda e^{-\lambda s}\Big( (2p-1)\, c - (1-p)V'(t + \tau - s)\Big),$$

and abusing notation slightly

$$y(t; p, \tau) := -\int_0^t \dot{y}(s; p, \tau, t) ds. \tag{2}$$

The root $y(t; q(\tau), \tau) = 0$ implicitly defines the maximum time interval in which the agent with belief $q(\tau)$ works on the diligent solution if he expects to work $\tau$ periods on the creative solution conditional on no progress.[4]

**Lemma 6** (Diligent Period)**.** *If the agent starts throwing Hail Marys at remaining time* $\tau_3$*, then the total time he spends on the diligent solution is given by*

$$\tau_2(\tau_3) = \min\Big(\{t > 0 : y(t; q(\tau_3), \tau_3) = 0\} \cup \{T - \tau_3\}\Big).$$

[3] A computer program to numerically determine the optimal policy for any parameter set is available from the authors.

[4] The belief stays constant during any time interval in which no effort is attributed to the creative path.

Finally, given a target belief $q$, the agent's first time interval on the creative path is given by

$$\tau_1(q) := \frac{1}{\lambda} \ln \left( \frac{p_0(1-q)}{q(1-p_0)} \right)$$

**Lemma 7** (Initial Creative Period)**.** *If the agent starts throwing Hail Marys at remaining time $\tau_3$, the agent spends $\tau_1(q(\tau_3))$ in the initial creative period.*

Combining the result of Lemma 5 to 7 provides us with a characterization of the optimal policy.

**Proposition 4** (Optimal Policy – Characterization)**.** *The optimal policy is unique. It is the solution to the fix point problem $T(\tau_3) = \tau_1(q(\tau_3)) + \tau_2(\tau_3) + \tau_3$.*

We conclude the characterization with a corollary to Proposition 4. It states that it is indeed optimal for the agent to work, if $B$ is large and no solution has been found

**Corollary 2.** *For any $p_0$, there exists a $\widetilde{B}$ such that whenever $B > \widetilde{B}$ it is optimal for the agent to work unless he has found a solution.*

### Optimal Policy – Properties

We now discuss the properties of the optimal policy. The first result implies that increasing the deadline does not reduce the agent's amount of effort devoted to a creative solution in case he fails to find a solution.

**Corollary 3.** *The agent's belief at the deadline is non-increasing in $T$. Moreover, both the maximum time the agent works on the creative solution and the maximum time the agent works on the diligent solution are non-decreasing in $T$.*

An immediate implication of this result is that whenever the deadline is expanded the agent does not reallocate his time completely. Instead, upon failure he has devoted at least the same amount of time to the creative and the diligent path before. The additional increment is then divided optimally between these paths. Our next result concerns the limit when the time horizon is large.

**Proposition 5.** *As the agent's time horizon approaches infinity, the maximum time he works on the diligent solution approaches infinity as well. If $p_0 > 1/2$, the agent's belief while working on the diligent solution approaches $1/2$, and the likelihood of a creative solution converges to $2p_0 - 1$. If $p_0 < 1/2$, the agent almost surely does not work on the creative solution.*

The first implication of this result is that as long as the time horizon is not infinite the agent will maintain a belief of at least 1/2 until his final switch to the creative path. Consequently the agent will stop working on the creative path despite being positive about its feasibility and then switch to the diligent path. Only if he is unlucky on the diligent path, he returns to the creative path.

The second implication of this result is that an increase $T$ beyond $q^{-1}(1/2)$ if $p_0 < 1/2$ only induces an increase in diligent work before the Hail Mary period. That is the agent is not willing to frontload any creative work – no matter how long the deadline – if he is not optimistic about its feasibility.

Corollary 3 and Proposition 5 only provide a limited understanding of the expected type of the solution. Our next result addresses that issue.

**Proposition 6.** *Let $\overline{\tau}_3 := q^{-1}(p_0)$. The likelihood of a solution is increasing $T$. Moreover, the following holds.*

1. *If $T < \overline{\tau}_3$ any solution is a creative solution*
2. *If $\overline{\tau_3} < T < \tau_2(\overline{\tau_3}) + \overline{\tau}_3$ solutions can be both diligent an creative. As $T$ increases the likelihood of a diligent solution increases while the likelihood of a creative solution decreases.*
3. *If $\tau_2(\overline{\tau_3}) + \overline{\tau}_3 < T$ solutions can be both diligent an creative. As $T$ increases the likelihood of a creative solution increases.*

## 3.2 Dynamic Choice: Only the Creative Solution Pays

In this part, we briefly discuss the case in which the agent receives $B$ only if he finds a creative solution. We are brief in this part since results are a mere application of the well-known results from the single-player version of Keller, Rady, and Cripps (2005). At each instance, the agent works if and only if $\lambda p_t B > c$. The agent becomes less optimistic over time. Thus after a finite time, $\hat{\tau}$, of working on the creative solution the agent gives up on finding a solution. We summarize the results as follows.

**Proposition 7** (Policy Only Creative Task)**.** *There is a threshold time $\hat{\tau}$ such that the agents works on the creative solution throughout if $T < \hat{\tau}$. He works for time $\hat{\tau}$ on the creative solution and does not work for the remaining time $T - \hat{\tau}$ if $T \geq \hat{\tau}$.*

**Corollary 4.** *Any solution is creative. The likelihood of a solution is increasing in $T$ if $T < \hat{\tau}$, and constant if $T \geq \hat{\tau}$.*

Figure 1 represents these results and compares them to those from Proposition 6.

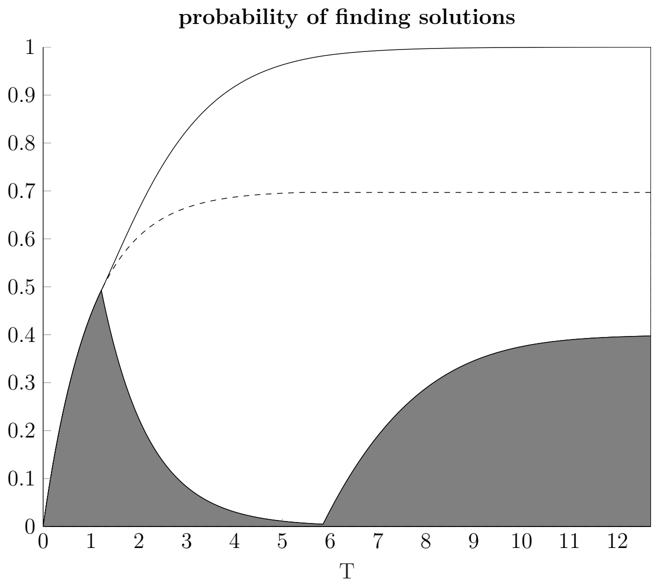


Figure 1: The solid line depicts the likelihood of finding any solution if $\rho = 1$, the shaded area represents the likelihood of a creative solution if $\rho = 1$, the dashed line is the likelihood of finding a (creative) solution if $\rho = 0$.

We conclude this part with a result for the case in which $B$ and $T$ are large similar to Proposition 5 for the case $\rho = 0$.

**Corollary 5.** *For $B$ sufficiently large the following holds. As the agent's time horizon approaches infinity, the likelihood of a creative solution converges to $p_0$.*

## 3.3 Dynamic Project Choice: Diligent Solution Pays Less

Finally, we address the case in which $\rho \in (0, 1)$. There are several interpretations of that case.

One interpretation is that the diligent solution is sometimes perceived as "obvious" and therefore does not qualify as a solution. Consider a researcher who carefully combines well understood concepts to solve a new problem. Sometimes such a combination is considered a contribution in itself other times it is not. Aware of that risk, the researcher attaches a probability smaller than 1 to his solution providing a sufficient contribution indeed.

Another interpretation is that while the contract only wants to award creativity, sometimes it is undetectable if the solution is creative. Consider a politician that conducts a labor reform. The reform either implies a structural change in the labor market with positive long-run effects, or creates a short-lived job boom only. While the politician needs creativity for the former, the later can be achieved employing well known political tricks. The voter may not always observe what is behind the reform. However, sometimes the political debate will disclose the shortcomings of the reform in which case the politician is not reelected.

Finally, a third interpretation is that the diligent solutions pay less, because creative solutions have a higher value. Consider a worker in an R&D department. On the one hand, if he comes up with a new innovative product, there is a high market value to it. On the other hand, if he improves the design of an existing product, he also creates market value albeit less so. Thus, product innovation may pay the agent more than process innovation.

Within the model, $\rho$ measures the value of a diligent solution to the agent. Reducing $\rho$ simply makes the diligent path less attractive. Consequently, we have to adjust the value of progress on the diligent path to

$$\widehat{V}(\tau;\rho) = \left(\rho B - \frac{c}{\lambda}\right)(1 - e^{-\lambda\tau}),$$

That delivers a new function[5]

$$\hat{q}(\tau_3) := \frac{\lambda(\hat{V}(\tau) + c\tau)}{\lambda(V(\tau) + c\tau) + c + V'(\tau)}.$$

Other than that, none of the reasoning changes. The cutoff 1/2 is replaced by a new cutoff

$$\hat{p}(\rho) := \frac{c}{2c + \lambda(1-\rho)B} \leq \frac{1}{2}$$

**Corollary 6.** *The agent never works on the diligent solution if $\rho \leq p_t$. the following holds. After generalizing the cutoff 1/2 to $\hat{p}(\rho)$, Proposition 3 applies if $\rho > p_0$. After generalizing the value $V(\tau)$ to $\widehat{V}(\tau;\rho)$ and $q(\tau_3)$ to $\hat{q}(\tau_3)$, Proposition 4 applies if $\rho > p_0$. All other results hold under the generalized terms conditional on $\rho > p_t$.*

## 3.4 The Principal's Problem

The principal's problem is to pick the deadline $T$ and the precision $\rho$ subject to the agent's choices. Let $\mathbb{P}^d$ be the (ex-ante) probability that the agent obtains diligent

[5] The function $V$ in the denominator is derived from work on the creative solution and thus remains at the value $V$. See proof of Lemma 2 for details.

solution by $T$ and the $\mathbb{P}^c$ the (ex-ante) probability of a creative solution by time $T$

$$\begin{aligned}
&\max_{T,\rho} \quad \mathbb{P}^c(\rho, T) + \alpha \mathbb{P}^d(\rho, T) \\
\text{s.t.} \quad & \tau_3 \text{ solves } T(\tau_3) = \tau_1(\hat{q}(\tau_3)) + \tau_2(\tau_3) + \tau_3, \\
& \text{and} \quad \mathbb{P}^c(\rho, T) = p_0\left(1 - e^{-\lambda\tau_1}\right) + \left(p_0 e^{-\lambda\tau_1}\right) e^{-\lambda\tau_2}\left(1 - e^{-\lambda\tau_3}\right) \\
& \mathbb{P}^d(\rho, T) = \left(p_0 e^{-\lambda\tau_1} + 1 - p_0\right)\left(1 - e^{-\lambda\tau_2} - \lambda\tau_2 e^{-\lambda(\tau_2+\tau_3)}\right).
\end{aligned} \tag{P}$$

**Optimal Approval**

In this part we fix the time interval $T$ and solve for the optimal approval rate $\rho$. We focus on the case in which the approval rate can be set at no cost and any approval is possible $\underline{\rho} = 0, \overline{\rho} = 1$. Extension to positive cost is straightforward. For any approval rate $\hat{\rho}$, we define

$$\hat{\alpha}(\rho) := \frac{\min\left\{p_0\left(1 - e^{-\lambda T}\right), p_0 - \frac{c}{\lambda B}\right\} - \mathbb{P}^c(\rho)}{\mathbb{P}^d(\rho)}.$$

md

**Lemma 8.** *Fix an approval rate $\hat{\rho} \in (0, 1]$, such that $\hat{\alpha}(\hat{\rho})$ is defined. The principal is indifferent between no approval, $\rho = 0$, and approval rate $\rho = \hat{\rho}$ if and only if $\alpha = \hat{\alpha}$.*

*Proof.* The principal is indifferent if $P^c(\rho = 0) = P^c(\hat{\rho}) + \alpha P^d(\hat{\rho})$. The left-hand side solves a standard two-armed bandit problem and thus implies $P^c(\rho = 0) = \min\left\{p_0\left(1 - e^{-\lambda T}\right), p_0 - \frac{c}{\lambda B}\right\}$. Solving for $\alpha$ proves the Lemma 8. □

From the principal's perspective $\hat{\alpha}$ serves as a cutoff and is strictly between 0 and 1 whenever it is defined.

**Corollary 7.** *For any $\alpha > \hat{\alpha}$ the principal strictly prefers to approve with $\hat{\rho}$ upon no approval, for any $\alpha < \hat{\alpha}$ the principal strictly prefers no approve upon $\hat{\rho}$. Moreover, if $\hat{\alpha}$ exists, $\hat{\alpha} \in [0, 1]$.*

Lemma 8 and Corollary 7 compare partial approval to no approval. Generalizing this argument we can find the optimal approval policy. To align the agent's preferences with her own a principal would always want to overcompensate the agent for a diligent solution relative to the principal's value of such a solution. The next proposition state this result. The proof in the appendix is constructive and implicitly determines the optimal $\rho^*(\alpha)$.

**Proposition 8.** *Suppose the principal has some value for any solution, that is $\alpha > 0$ and $T$ is long enough. Then, the optimal approval policy of the principal is described by an increasing function $\rho^*(\alpha) \geq \alpha$.*

The agent's optimal policy takes three aspects into account: (i) the creative solution bears the fundamental risk of non-existence, (ii) the diligent solution bears the risk of non-approval, and (iii) the diligent solution requires more steps and is therefore more costly in expectations. The principal shares the first concern, wants to create the second concern to screen the agent, but wants to mitigate the agent's third concern.

To align the preferences over the two types of solutions the principal picks an approval rate $\rho > \alpha$. The principal has to promise the agent a higher approval rate than her own relative preference to account for the higher cost of the diligent path.

### Optimal Deadline

In this part we fix the approval policy $\rho \in (0, 1]$ and solve for the optimal deadline $T$. As in the previous part we focus on the case in which the deadline can be chosen at no cost. We start by addressing the two polar cases in the principal's preferences $\alpha = 0$ and $\alpha = 1$. It is straight-forward that $\alpha = 1$ implies that the principal's optimal deadline is $T = \overline{T}$. The principal equally values both types of solutions and the likelihood of obtaining either approaches 1 as $T = \overline{T}$.

Next, assume the principal has no value for a diligent solution, $\alpha = 0$.

**Lemma 9.** *Suppose $\alpha = 0$ and $\rho = 1$. The optimal deadline $T^* = q^{-1}(p_0)$. That is, the principal's sets the deadline to the largest value that guarantees that the agent never works on a diligent solution.*

Although increasing the time horizon has no direct cost, the principal faces a trade off. She wants to give the agent enough time to work on the creative task as much as possible to increase the chance of obtaining a creative solution. Yet, she wants to limit the agent's time horizon sufficiently much such that the creative solution is not crowded out by a diligent solution.

The trade-off described makes it immediate that the principal should never pick $T$ such that the first interval of working on a creative solution $\tau_1 = 0$, and the interval of working on a diligent solution is positive $\tau_2 > 0$. Yet, by Corollary 3 we know that for long time horizons that imply $\tau_1 > 0$ the agent's maximal effort devoted to finding a creative solution is larger than under short or intermediate time horizons.

To solve the principal's trade-off, however, the expected effort is relevant. Since the agent is aware of the risk of a Hail Mary, he precautionarily stops looking for a creative solution and switches to the diligent path relatively early. Moreover, any progress during that diligent phase implies that he will not return to the creative path.

Both the length of the early creative phase and the late creative phase are bounded by a finite number. Thus, as $T$ grows large the length of the diligent phase grows arbitrarly large. Because the diligent solution has no fundamental risk of availability this observation implies that the likelihood of returning to work on the creative solution once the agent switches to the diligent phase becomes arbitrarily small.

The final observation leading to the result of Lemma 9 is the following. The early creative phase never exceeds the maximum length of the late creative phase that the principal can generate by an appropriate choice of $T$. That maximum length is generated precisely if the deadline is chosen such that the agent never works on a diligent solution.

Combining Lemma 9 with continuity of the principal's payoffs in $\alpha$, and with continuity of the agents policy parameters $(\tau_1, \tau_2, \tau_3)$ in $T$implies that there is a weakly increasing function $T(\alpha)$ for the optimal deadline. In particular, the following proposition show that the optimal deadline is of one of only two potential types.

**Proposition 9.** *Suppose $\overline{T}$ is large enough. For any $\rho$ and there exists a cutoff $\tilde{\alpha}$ such that the optimal deadline is $T^* = \min\{\hat{q}^{-1}(p_0), \overline{T}\}$ for $\alpha < \tilde{\alpha}$ and $T^* = \overline{T}$ for $\alpha > \tilde{\alpha}$.*

The proposition shows that for low values of $\alpha$, the principal chooses a low deadline such that the agent only works on the creative task, while for high values of $\alpha$, she chooses a very long deadline such that the agent will eventually find a solution almost surely.

### Optimal Deadline and Approval

If the principal can optimally choose both the deadline and the approval rate she combines both tools to balance the tradeoff between generating output and screening the agent. By extending the deadline, she unambiguously increases the probability of obtaining a solution. Yet, long deadlines make the diligent task more attractive. By reducing the approval probability of the diligent task, she reduces that attractiveness. Screening, in turn, increases. As the following proposition shows, the principal chooses one of two policies depending on her preference parameter $\alpha$.

**Proposition 10.** *There is a cutoff value $\check{\alpha} \leq \frac{2c}{B\lambda}$ such that for $\alpha \leq \check{\alpha}$ the principal chooses $\rho = 0$ and $T = \hat{\tau}$,[6] the maximal time an agent will choose the creative task exclusively if the diligent task is not rewarded. If $\alpha > \check{\alpha}$, the principal chooses $T \to \infty$ and $\rho = \frac{2c}{B\lambda}$.*

The intuition behind this result is straightforward: if the principal values screening sufficiently much, she does not reward a diligent solution at all. Consequently, the diligent task does not crowd out the creative task. If the principal, to the contrary, values output sufficiently much, she chooses a long deadline to guarantee a solution almost surely. By choosing $\alpha < \rho < 1$, she disincentivizes early work on the diligent task such that the agent works for as long as possible on the creative task without giving up on diligent solutions eventually.

We interpret the two contracts as the following award schemes: either (i) the principal offers a probationary period and tenure if the agent proofs to be capable of creative solutions, or (ii) she offers instant tenure, with the potential to promote the agent. Promotion occurs with certainty upon a creative solution, it occurs randomly upon a diligent solution.

# 4 Conclusion

We present and analyze a model of dynamic project selection between a task that requires diligence but is generally feasible and a task that requires creativity but is not always feasible. We characterize the agent's optimal policy given a fix deadline and monitoring technology of the principal. We then turn to the principal's problem and characterize the optimal monitoring rule and the optimal deadline. Our results apply to academic research environments, political institutions, and corporate R&D.

[6] $\hat{\tau}$ is defined in Proposition 7.

# Appendix

## A Additional Terms: Optimal Control

In this part, we describe the optimal control problem. Let $A_t = \int_0^t a_t dt$ be the time the agent has spent working on a creative solution until time $t$.

**Hamiltonian.**

$$\mathcal{H} = e^{-\lambda(t-A)} \left( \left(1 - p_0 + p_0 e^{-\lambda A}\right)(1-a)\lambda V(T-t) + a p_0 e^{-\lambda A} \lambda B - c\left(1 - p_0 + p_0 e^{-\lambda A}\right)\right) + a\eta.$$

**Co-state evolution.**

$$\begin{aligned}
-\dot{\eta} = \frac{\partial H}{\partial A} =& \lambda e^{-\lambda(t-A)} \left( \left(1 - p_0 + p_0 e^{-\lambda A}\right)(1-a)\lambda V(T-t) \right. \\
& \left. + a p_0 e^{-\lambda A} \lambda B - c\left(1 - p_0 + p_0 e^{-\lambda A}\right)\right) \\
& - \lambda e^{-\lambda(t-A)}((1-a)p_0 e^{-\lambda A} \lambda V(T-t) + a p_0 e^{-\lambda A} \lambda B - c p_0 e^{-\lambda A}) \\
=& \lambda e^{-\lambda(t-A)}(1-p_0)\left((1-a)\lambda V(T-t) - c\right)
\end{aligned}$$

and boundary condition $\eta_T = 0$.

**Switching condition.**

$$\gamma = e^{-\lambda(t-A)} \left( \left(1 - p_0 + p_0 e^{-\lambda A}\right) \lambda V(T-t) - p_0 e^{-\lambda A} \lambda B \right) - \eta.$$

**(modified) evolution of $\gamma$.**

$$\frac{\dot{\gamma}}{\lambda e^{-\lambda(t-A)}} = \lambda p_0 e^{-\lambda A}(B - V(T-t)) - (1-p_0)c + \left((1-p_0) + p_0 e^{-\lambda A}\right) \dot{V}(t)$$

or, alternatively,

$$\dot{\gamma}_t = \lambda e^{-\lambda(t-A_t)} \left((1-p_0) + p_0 e^{-\lambda A_t}\right) \left(\lambda p_t (B - V(T-t)) - (1-p_t)c + \dot{V}(t)\right).$$

Substituting $V(T-t) = (B - c/\lambda)(1 - e^{-\lambda(T-t)})$

$$\begin{aligned}\dot{\gamma}_t &= \lambda e^{-\lambda(t-A_t)}\left((1-p_0) + p_0 e^{-\lambda A_t}\right)\left(p_t c - (1-p_t)\left(\lambda B e^{-\lambda(T-t)} + c(1 - e^{-\lambda(T-t)})\right)\right) \\ &= \lambda e^{-\lambda(t-A_t)}\left((1-p_0) + p_0 e^{-\lambda A_t}\right)\left((2p_t - 1)\, c - (1-p_t)\,(\lambda B - c)\, e^{-\lambda(T-t)}\right)\end{aligned}$$

# B Proofs

## B.1 Preliminary Lemma

The following Lemma will be useful for several proofs.

**Lemma 10.** *The minimum of $\gamma_t$ is either at 0 or $T$.*

*Proof.* Suppose to the contrary, that an interior minimum exists. $\gamma_t$ is continuously differentiable. Thus any interior minimum is a critical point. At the critical point we have

$$\dot{\gamma}_t = \underbrace{\lambda e^{-\lambda(t-A_t)}\left((1-p_0) + p_0 e^{-\lambda A_t}\right)}_{f(t)}\underbrace{\left((2p_t - 1)\, c - (1-p_t)\,(\lambda B - c)\, e^{-\lambda(T-t)}\right)}_{g(t)} = 0$$

Since $f > 0$, a critical point satisfies $g(t) = 0$. For the critical point to be a minimum we need to have that

$$\ddot{\gamma}_t = \dot{f}(t)g(t) + f(t)\dot{g}(t) = f(t)\dot{g}(t) > 0.$$

A necessary and sufficient condition for an interior minimum is thus $\{g(t){=}0, \dot{g}(t){>}0\}$. Taking the derivative,

$$\dot{g}(t) = -a_t p_t(1-p_t)\lambda\left(2c + (\lambda B - c)\, e^{-\lambda(T-t)}\right) - \lambda(1-p_t)\,(\lambda B - c)\, e^{-\lambda(T-t)} < 0.$$

A contradiction. □

## B.2 Proof of Proposition 1

*Proof.* When $T = \inf$, the evolution of the switching function becomes

$$\dot{\gamma}_t = e^{-\lambda(t-A_t)}\lambda\left(c(p_0 e^{-\lambda A_t} + 1 - p_0) - (1-p_0)(1-a_t)2(B\lambda - c)\right) \tag{3}$$

which is positive whenever $a_t = 1$. Combining this with Lemma 10 concludes the proof. □

## B.3 Proof of Proposition 2

*Proof.* When $c = 0$, the evolution of the switching function becomes

$$\dot{\gamma}_t = B\lambda^2(1-p_0)e^{-\lambda(T-A_t)}\Big((1-a_t)(1-2e^{-\lambda(t-T)})-1\Big) \tag{4}$$

which is negative independent of $a_t$. Hence, the agent either works on the creative task exclusively when $\gamma_0 < 0$ or starts with the diligent task and switches to the creative one eventually when $\gamma_0 > 0$. Note that $\gamma_T < 0$ independent of $\gamma_0$. □

## B.4 Proof of Lemma 1

*Proof.* $\gamma$ is continuous in $T$ and $\eta_T = 0$. Thus the final value for $\gamma$ is defined in terms of primitives,

$$\gamma_T = -p_0 e^{-\lambda T}\lambda B < 0.$$

By continuity there is a time $t < T$ such that $\gamma_t < 0$. □

## B.5 Proof of Lemma 2

*Proof.* Suppose to the contrary, that there is a setting in which the agent works on a creative solution until he either finds it or arrives at the deadline. Then, his value function for belief $p$ and remaining time $T$ is

$$Z^c(p,T) = B - \frac{1}{\lambda}\left(c + \frac{1}{p}\frac{\partial Z^c(p,T)}{\partial T}\right) - (1-p)\left(\frac{\partial Z^c(p,T)}{\partial p} + \frac{c}{p\lambda}\right) = pV(T) - (1-p)cT.$$

Further,

$$\frac{\partial Z^c(p,T)}{\partial T} = pV'(T) - (1-p)c$$
$$\frac{\partial Z^c(p,T)}{\partial p} = V(T) + cT$$

If the agent instead were to work on a diligent solution for one instance, and thereafter on a creative one her expected value is

$$Z^d(p,T) = V(T) - \frac{1}{\lambda}\left(c + \frac{\partial Z^c(p,T)}{\partial T}\right)$$

For the claim to hold we need that for any $T \leq \infty$, there is some $0 < p \leq p_0$ such that

$$
\begin{aligned}
& Z^d(p,T) \leq Z^c(p,T) \\
\Leftrightarrow \quad & \frac{pc}{\lambda} \geq (1-p)(V(T)+cT) - \frac{pV'(T)}{\lambda}.
\end{aligned}
$$

Given any $p < 1$, the RHS is continuous and as $T \to \infty$ the RHS becomes arbitrarily large and thus larger than the LHS for some finite $T$. A contradiction. □

## B.6 Proof of Lemma 3 and 4

The proofs of Lemma 3 and Lemma 4 directly follow from Lemma 10.

## B.7 Proof of Proposition 3

*Proof.* To prove Proposition 3 we state and prove the following lemma.

**Lemma 11.** *There exists a $T < \infty$ such that the agent works on a diligent solution on the interval $[t_1, t_2]$ and on a creative solution on the intervals $(0, t_1)$ and $(t_2, T]$ if and only if $g(t) = 0$ for some $t > 0$.*

*Proof.* The only-if part follows by continuity. By Lemma 10, $g(t) = 0$ implies a global maximum. By Lemma 2, $\gamma > 0$ at the maximum for $T$ large enough. Since $\dot{g} < 0$, $\dot{f} < 0$, and $g > 0$, $f > 0$ to the left of that maximum, $\gamma$ is strictly concave in that region. Thus, $\lim_{t \to -\infty} \gamma_t < M$ given any $T$ and any $M \in \mathbb{R}$, or equivalently, as $T \to \infty$, $\gamma_0 < 0$. □

If $p_0 > 1/2$, then $g(0) > 0$ for $T$ sufficiently large. By Lemma 2 it is not optimal for the agent to work exclusively on a creative solution. By Lemma 1 he eventually returns to working on a creative solution. By continuity, this implies $g(t) = 0$ for some $t > 0$. Lemma 11 concludes the proof. □

## B.8 Proof of Lemma 5

*Proof.* The agent works on a creative solution at the deadline. Using backward induction we can derive the agent's value function for he last period. From the proof of Lemma 2 we know the agent works on a creative solution from $T - \tau$ until

$T$ only if

$$\begin{aligned} p_{T-\tau}\frac{c}{\lambda} &\geq (1-p_{T-\tau})(V(\tau)+c\tau) - \frac{p_{T-\tau}}{\lambda}V'(\tau) \\ \Leftrightarrow p_{T-\tau} &\geq \frac{\lambda(V(\tau)+c\tau)}{\lambda(V(\tau)+c\tau)+c+V'(\tau)} =: q(\tau). \end{aligned}$$

□

## B.9 Proof of Lemma 6

*Proof.* $\dot{y}$ is the derivative of $\gamma$ assuming that the agent works for $\tau_3$ periods on a creative solution at the end, that the current belief is $p$, and that the total time spent working on a diligent solution is $t$. Integrating this gives us a solution to $y(t)$ the policy function at time 0 when the length to work on a diligent solution is $t$. By construction $y(0) = 0$

We look for $t > 0$ such that $y(t) = 0$ or alternatively the agent works on a diligent solution from the beginning and $\tau_2 = T - \tau_3$. □

## B.10 Proof of Lemma 7

*Proof.* Given $\tau_3$ we know that $q(\tau_3)$ determines the intermediate belief. To calculate the time to arrive at this intermediate belief, we need that the agent learns until $p_t = q(\tau_3)$ using the law of motion $\dot{p} = -\lambda p_t(1-p_t)a_t$ that implies that

$$\tau_1(q(\tau_3)) := \frac{1}{\lambda}\ln\left(\frac{p_0(1-q(\tau_3))}{q(\tau_3)(1-p_0)}\right)$$

□

## B.11 Proof of Proposition 4

*Proof.* We begin by stating a monotonicity result.

**Lemma 12.** *$q, \tau_1$, and $\tau_2$ are monotone. $\tau_1$ and $\tau_2$ are decreasing, $q$ is increasing.*

For now, assume Lemma 12 holds. We verify it at the end.

Now, fix any $\tau_3$ such that $q(\tau_3) \leq p_0$. Then $q(\tau_3)$ determines the belief the agent has to have to be indifferent between working on a creative solution and on a diligent solution with time $\tau_3$ remaining. Moreover, $\tau_2(\tau_3)$ determines how long an agent with belief $q(\tau_3)$ prefers to work exclusively on a diligent solution assuming that he works on a creative solution in the final interval of length $\tau_3$. Finally, $\tau_1(q(\tau_3))$ determines the length the agent has to work on the creative solution to hold a belief of $q(\tau_3)$ during the last two intervals. Thus, for any potential choice of $\tau_3$, $\tau_2(\tau_3)$ and $\tau_1(\tau_3)$ determine the associated policies, assuming one of the three profiles {creative}, {diligent,creative}, {creative,diligent,creative}.

Using Proposition 3 it is sufficient to restrict to these policies and thus existence is guaranteed.

To show uniqueness we have to show that no other $\tau_3'$ that solves the fix point problem exists. Uniqueness is guarantee in all cases in which the agent works for at most one interval on a creative solution. Then he works on a creative solution only in the end and $q(\tau_3) = p_0$ and thus $\tau_3$ is unique.

Uniqueness is less obvious if the agent splits working on the creative solution on two disjoint intervals. Assume this is the case. To arrive at a contradiction, assume that a $\tau_3'$ exists. Further, assume (without loss) that $\tau_3' > \tau_3$. Both, $\tau_3$ and $\tau_3'$ have a associated terminal beliefs, $\bar{p}$ and $\bar{p}'$. The terminal belief is the belief the agent holds at the deadline conditional on failing to find any solution. We proceed by cases and derive a contradiction for each of them.

First, assume $\bar{p} > \bar{p}'$. Consider the agent's belief with $\tau_3$ periods remaining assuming he worked on a creative solution for $\tau_3' - \tau_3$ periods with initial belief $q(\tau_3')$. Since $\bar{p} > \bar{p}'$, the agent has to have a a belief $\tilde{q} < q(\tau_3)$ with $\tau_3$ periods remaining. But, then the agent prefers to work on the diligent solution with $\tau_3$ periods remaining. A contradiction.

Next, assume that $\bar{p} = \bar{p}'$. Conditional on not having obtained a success after $\tau_3' - \tau_3$ the agent is then indifferent in his choice. Using the arguments of the proof of Lemma 10, the agent's policy function has no interior minimum. Thus, the agent has to be indifferent on the entire interval. But then concavity of $\gamma$ at any critical point prohibits that. A contradiction.

Finally, assume $\bar{p} < \bar{p}'$. In that case the agent's overall working time on the creative solution is smaller under $\tau_3'$ than under $\tau_3$. Thus, $\tau_2(\tau_3') > \tau_2(\tau_3)$ for both to be a solution to the fix point problem. By Lemma 12, $\tau_2$ decreases in $\tau_3$. A contradiction. □

**Proof of Lemma 12**

*Proof.* Monotonicity of $\tau_1$ is trivial. Monotonicity in $q$ follows from its form $A(t)/(A(t)+B(t))$. It is monotone increasing if

$$\underbrace{\lambda(V'(t)+c)}_{A'}\underbrace{(c+V'(t))}_{B}-\underbrace{V''(t)}_{B'}\underbrace{(\lambda(V(t)+ct))}_{A}>0$$

which holds since $V(t)$ is positive, increasing and concave.

Finally, if $\tau_2(\tau_3)$ is the root of $y$, we use the implicit function theorem. Abusing notation we obtain

$$\frac{\mathrm{d}y(\tau_2(\tau_3);\tau_3)}{\mathrm{d}\tau_3}=\frac{\partial y(\tau_2;\tau_3)}{\partial\tau_3}+\frac{\partial y(\tau_2;\tau_3)}{\partial t}\frac{\partial\tau_2(\tau_3)}{\partial\tau_3}=0.$$

Using that $q$ is increasing we obtain that

$$\frac{\partial\dot{y}(s;q(\tau),\tau,t)}{\partial\tau}=e^{-\lambda s}\left(2\frac{\partial q(\tau)}{\partial\tau}c+\frac{\partial q(\tau)}{\partial\tau}V'(t+\tau-s)+(1-p)\lambda V'(t+\tau-s)\right)>0,$$

which implies $\partial y(t;\tau_3)/\partial\tau_3<0$. Using the arguments from the proof of Lemma 10, $y(t;\tau_3)$ is decreasing in $t$ at $t=\tau_2(\tau_3)$. $T-\tau_3$ is decreasing as well and the max preserves monotonicity. Thus $\tau_2$ is decreasing. □

## B.12 Proof of Proposition 5

*Proof.* By Proposition 3 a belief $q(\tau_3)<1/2$ cannot be implemented whenever $\tau_1(\tau_3)>0$. Since $p_0>1/2$, $q(\tau_3)<1/2$ cannot be implemented at all. But then, $\tau_3$ is bounded and so is $\tau_1(\tau_3)$. Therefore as $T\to\infty$, $\tau_2\to\infty$. That requires an intermediate belief $q(\tau_3)$ converging to $1/2$ by Lemma 11 if $p_0>1/2$.

As $T\to\infty$, $\tau_2(\tau_3)\to\infty$. Thus, whenever the agent enters phase in which he works on a diligent solution he almost surely obtains it before that phase ends. If $p_0<1/2$ the agent starts in the diligent phase. When $p_0>1/2$ the agent begins with the first creative phase. The ex-ante probability of leaving the first phase without a solution is $p_0e^{-\lambda\tau_1}$. Since $q(\tau_3)\to 1/2$, $p_0e^{-\lambda\tau_1(q(\tau_3))}\to 2(1-p_0)$. Thus the likelihood of finding a creative solution within that time is $2p_0-1$. □

## B.13 Proof of Proposition 6

*Proof.* If the agent strictly prefers to work on a creative solution for the entire period, her terminal belief is determined by the law of motion of $p$, that is $\dot{p}=-p(1-p)\lambda$ which decreases. Increasing $T$ implies a decrease in the terminal belief $\bar{p}$. If the agent strictly prefers working on the creative solution only in one interval, then increasing the deadline implies at most an increase in the time spend on the creative solution. Thus $\bar{p}$ never rises. Finally, if the agent splits her time working on a creative solution on two disjoint intervals, the terminal belief can only decrease if $\tau_2$ increases. An increase in $\tau_2$ implies a decrease in $\tau_3$. Now suppose $\bar{p}$ increases. Given $\bar{p}$ we can construct the belief at each point in time in that last interval using the law of motion $\dot{p} = -p(1-p)\lambda$. A higher terminal belief implies a higher belief at any point in time in that interval. Because the agent strictly prefers working on the creative solution anywhere in the interior of the interval using the terminal belief $\bar{p}$, he has to prefer working on it under any $\bar{p}' > \bar{p}$ and thus, $\tau_3$ cannot increase. Therefore, $\bar{p}$ decreases.

For the last part we have to show that $\tau_2$ is not strictly decreasing. A necessary condition for a decrease is an increase in $\tau_3$. The terminal belief $\bar{p}$ is non-increasing. But then $\tau_2(\tau_3)$ cannot decrease. □

## B.14 Proof of Proposition 7

*Proof.* The proof follows from the single player version of the model of Keller, Rady, and Cripps (2005) □

## B.15 Proof of Proposition 8

*Proof.* We proof Proposition 8 constructive and in four steps. First we show that the principal wants to increase $\rho$ if and only if $\alpha \geq \frac{p_{\tau_1}}{(1-e^{\lambda\tau_3})}$. Then we use the agent's last indifference condition at the last switching time to derive an implicit solution for the optimal $\rho$. We show that this solution is indeed larger than $\alpha$. Finally, we use supermodularity of the principal's utility to prove monotonicity

**Step 1.** The principal's utility is

$$\begin{aligned} U^p(\rho) &= \mathbb{P}^c(\rho) + \alpha\mathbb{P}^d(\rho) \\ &= p_0\left(1 - e^{-\lambda\tau_1}\right) + \left(p_0 e^{-\lambda\tau_1}\right) e^{-\lambda\tau_2}\left(1 - e^{-\lambda(T-\tau_1-\tau_2)}\right) + \\ &\quad \alpha\left(p_0 e^{-\lambda\tau_1} + 1 - p_0\right)\left(1 - e^{-\lambda\tau_2} - \lambda\tau_2 e^{-\lambda(T-\tau_1)}\right) \end{aligned}$$

If the agent's optimal policy is to only work on $c$, that is, if $T$ is small, a marginal change in $\rho$ has no effect. We thus address the case in which $\tau_2 > 0$. Applying Corollary 6 implies $\frac{\partial\tau_2}{\partial\rho} > 0$ and thus.

$$\operatorname{sign}\left(\frac{\partial U^p(\rho)}{\partial\tau_2}\right) = \operatorname{sign}\left(\frac{\partial U^p(\rho)}{\partial\rho}\right).$$

Taking the derivatives and simplifying implies that

$$\operatorname{sign}\left(\frac{\partial U^p(\rho)}{\partial\rho}\right) = \operatorname{sign}\left(\alpha - \frac{p_{\tau_1}}{1 - e^{-\lambda\tau_3}}\right).$$

**Step 2.** We use the agent's indifference at the last switching time $t = T - \tau_3$. Define

$$\Upsilon^d(\varepsilon) := p_t V(\tau_3 - \varepsilon) - (1 - p_t)c(\tau_3 - \varepsilon)$$
$$\Upsilon^c(\varepsilon) := p_{t+\varepsilon} V(\tau_3 - \varepsilon) - (1 - p_{t+\varepsilon})c(\tau_3 - \varepsilon)$$

with $p_{t+\varepsilon} = \int_t^{t+\varepsilon} \lambda p_{t+s}(1 - p_{t+s})ds + p_t$. $\Upsilon^d$ describes the agent's continuation value of working on the creative solution from $t + \varepsilon$ if he works on the diligent solution in the interval $\varepsilon$. $\Upsilon^c$ is that value if he works on the creative solution in that interval. The agent is indifferent between either task at $t$ by construction, he works on the creative solution thereafter by Lemma 1, and the continuation value is continuous. Thus, the following holds

$$\left(\rho B - \frac{c}{\lambda}\right)(1 - e^{-\lambda\tau_3}) + \lim_{\varepsilon\to 0} e^{-\lambda\varepsilon}\frac{\Upsilon^d(\varepsilon)}{\lambda} = p_t B + \left(p_t e^{-\lambda\varepsilon} + (1 - p_t)\right)\lim_{\varepsilon\to 0}\frac{\Upsilon^d(\varepsilon)}{\lambda}.$$

The optimal (interior) $\rho$ for the principal solves that equation subject to $\alpha = \frac{p_t}{(1-e^{-\lambda\tau_3})}$.

**Step 3.** Rearranging the indifference condition from step 2 yields

$$\left(\rho - \frac{p_{\tau_1}}{(1 - e^{-\lambda\tau_3})}\right)B = \frac{1}{\lambda(1 - e^{-\lambda\tau_3})}\left(\lim_{\varepsilon\to 0} e^{-\lambda\epsilon}\Upsilon^d(\varepsilon) - p_{\tau_1}\Upsilon^c(\varepsilon) - (1 - p_{\tau_1})\Upsilon^c(\varepsilon)\right) + \frac{c}{\lambda}.$$

The RHS is (strictly) positive because $\Upsilon^d(\varepsilon) \geq \Upsilon^c(\varepsilon)$. The LHS must be positive at the optimal $\rho$. Using step 1, that implies that $\rho > \alpha$.

**Step 4.** Single crossing implies monotone comparative statics. Taking the derivative of $U^p$ with respect to $\alpha$ yields $\mathbb{P}^d(\rho)$ which is increasing in $\rho$.

□

## B.16 Proof of Lemma 9

*Proof.* We organize the proof as follows. We first proof the case $p_0 < \hat{p}$. Then we turn to the case $p_0 > \hat{p}$.

**Case 1:** $p_0 < 1/2$. $P^c = p_0 e^{-\lambda\tau_2}(1 - e^{-\lambda\tau_3})$ and $\tau_3 = q^{-1}(p_0), \tau_2 = T - \tau_3$. Thus, the optimal $\tau_2 = 0$.

**Case 2:** $p_0 > 1/2$. Any deadline $T$ such that $\tau_1 = 0$ and $\tau_2 > 0$ is suboptimal for the same reasons as in Case 1. The amount worked on the creative solution in the beginning $\tau_1$ is increasing in $T$ by appendix B.11 in the proof of Proposition 4. Thus for any $T < \infty$ such that $\tau_1 > 0$, any $T' > T$ increases $\tau_1$ and is thus preferred if the principal values the creative task. As $T \to \infty$, $\tau_2 \to \infty$

by Proposition 5 and $\tau_3$ becomes irrelevant.

What remains is to show that $\tau_3 = q^{-1}(p_0) > \lim_{T\to\infty} \tau_1$.

We show first that this claim holds for $c \to 0$. Then we show that $q$ increases in $c$. By Proposition 4 as $T \to \infty$, $\tau_1 \to \frac{-\ln\left(\frac{1-p_0}{p_0}\right)}{\lambda}$. As $c \to 0$, $q(\tau_3) \to (1-e^{-\lambda\tau_3})$ which implies $\tau_3 = \frac{-\ln(1-p_0)}{\lambda}$. Because $p_0 < 1$ this implies $\tau_3 > \tau_1$.

To show that $q$ increases in $c$, we study how the maximal $T$ such that the agent works only on creative varies with $c$. The solution is given by the indifference condition in the switching under the assumption that the agent only works on the creative task, i.e.,

$$0 = \gamma_0$$
$$0 = -e^{-\lambda T}(B\lambda - c) + (1-p_0)(B\lambda + c\lambda T) - c$$

which delivers as solution for $T$

$$T^c = \frac{1}{\lambda}\left(-\frac{B\lambda - c}{c} + \frac{p_0}{(1-p_0)} + W\left(\frac{e^{\frac{B\lambda-c}{c} - \frac{p_0}{1-p_0}}(B\lambda - c)}{c}\frac{1}{1-p_0}\right)\right)$$

where $W$ denotes the Lambert-$W$ function. Note that $c$ only appears in the form of $x(c) := \frac{B\lambda - c}{c}$ which is decreasing in $c$. The argument of the Lambert-$W$ is positive and, hence, we know that it is concave in the relevant range. Finally, because the derivative of the Lambert-$W$ is one at zero, it follows that $\frac{dT^c}{dx(c)} < 0$ and as $x(c)$ is decreasing in $c$, $\frac{dT^c}{dc} > 0$.

□

## B.17 Proof of Proposition 9

*Proof.* When $\tau_1 = \tau_2 = 0$ and $\tau_3 > 0$ as well as when $\tau_1 > 0, \tau_2 > 0$, and $\tau_3 > 0$, both the probability of any success and the probability of a creative success are increasing. Hence, conditional on being in these regions, the principal prefers the maximal deadline within the region. The only possible interior solution is when $\tau_1 = 0$ and $\tau_2 > 0, \tau_3 > 0$. Suppose there is an interior solution. This implies that there has to be a critical point when the objective is concave.

Towards a contradiction, we show that whenever the objective is concave in $T$, it must be strictly increasing. Recall the objective

$$\begin{aligned} U^p(T) &= \mathbb{P}^c + \alpha \mathbb{P}^d \\ &= p_0 e^{-\lambda \tau_2}(1 - e^{-\lambda \tau_3}) + \alpha(1 - e^{-\lambda \tau_2} - \lambda \tau_2 e^{-\lambda T}) \end{aligned}$$

and differentiate with respect to $T$ taking to account that in the relevant region $\frac{d\tau_2}{dT} = 1$ and $\frac{d\tau_3}{dT} = 0$

$$\begin{aligned} \frac{dU^p(T)}{dT} &= -\lambda \left( p_0 e^{-\lambda \tau_2}(1 - e^{-\lambda \tau_3}) - \alpha(e^{-\lambda \tau_2} - e^{-\lambda T} + \lambda \tau_2 e^{-\lambda T}) \right) \\ &= -\lambda \left( U^p(T) - \alpha(1 - e^{-\lambda T}) \right) \\ \frac{d^2 U^p(T)}{dT^2} &= \lambda^2 \left( U^p(T) - \alpha(1 - 2e^{-\lambda T}) \right). \end{aligned}$$

Because $e^{-\lambda T} > 0$, it follows that if $U^p(T)$ is concave, it is strictly increasing. A contradiction to the assumption of the existence of an interior solution. Hence, any optimal deadline is either infinite or given by $T^c$. □

## B.18 Proof of Proposition 10

*Proof.* By Proposition 9, we know that – independent of $\rho$ – the optimal deadline is either a short one under which the agent only works on the creative task or a very long one under which a solution is guaranteed almost surely. For the short deadline, the principal's payoff increases in the length of the creative interval. This cutoff is defined by the indifference condition as in the proof of Lemma 9. It is maximized when $\rho = 0$ and the solution corresponds to the one-player solution as in Keller, Rady, and Cripps, 2005 (see Proposition 7). If the long deadline is chosen, the principal's utility is increasing in $\tau_1$. To maximize $\tau_1$, the principal again reduces $\rho$. However, it can not be reduced too much as otherwise the agent never starts working on the diligent task. Hence, the lower bound on $\rho$ is given by the condition that working on the diligent task is profitable.

$$\lambda(\rho B - \frac{c}{\lambda}) - c \geq 0.$$

Clearly, for $\alpha = 0$, the principal wants to induce only creative work while for $\alpha = 1$, she wants to induce the highest possible solution probability and chooses $T \to \infty$. The result then follows by monotonicity and continuity of the principal's profit in $\alpha$. □

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