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At the Crossroad of Research: The Impact of Projection Bias on the Decision to Explore or Exploit Ideas

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At the Crossroad of Research: The Impact of Projection Bias on the Decision to Explore or Exploit Ideas*

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Abstract

Focusing on projection bias and overconfidence/underconfidence, we demonstrate the effects of projection bias on the decision of a researcher to delve deeper into the current research idea or explore a new one in infinite periods. We consider a researcher who has a belief regarding whether other researchers have already come up with the same idea. Although beliefs dominated by overconfidence/underconfidence are consistent over time, beliefs dominated by projection bias are inconsistent, depending on whether the researcher has obtained a new idea. We show that a researcher with projection bias changes ideas more often than overconfident/underconfident researchers. Moreover, successful researchers are more likely to have projection bias when the required value of the research outcome for success is sufficiently high. Our results have implications for the file drawer problem, which is the tendency of researchers to shelve negative or insignificant results.

JEL Classification: D83, D91

Keywords: Projection bias, Over/underconfidence, Selectiveness, Explore or exploit ideas, File drawer problem

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1 Introduction

Researchers are searching for novel research ideas. Once they find an intriguing one, they must assess whether it is worth pursuing. If they throw away one idea, they begin to explore other new ideas. This study considers a researcher facing a trade-off between delving deeper into the current research idea and exploring a new one. The uncertainty regarding the success of the current idea tangles with this trade-off. Furthermore, even if the researcher is confident in the current idea, s/he is plagued by doubts that other researchers have already had the same idea but judged it as not promising or that they tried but failed with the idea. The source of this doubt is related to the *file drawer problem* (Rosenthal, 1979) : Researchers are more likely to publish studies with positive or significant results than those with negative or insignificant results; the latter end up in the researchers' drawers.[1 2] Indeed, this concern has pros and cons for the researcher's attitude. On the positive side, it prevents the researcher from clinging to the current idea, which seems unlikely to succeed. On the negative side, it makes the researcher discard a promising idea. Consequently, this concern has influenced the extent to which researchers have succeeded in academia. Importantly, when researchers assesse the value of a current idea, behavioral biases considerably influence their decisions.[3] In this study, focusing on interpersonal projection bias and over/underconfidence, we demonstrate the effects of projection bias on a researcher's decision to explore a new idea or exploit the current idea.

We consider a researcher who has a belief about whether other researchers have already come up with the same idea. Overestimating (underestimating) this probability leads to underconfidence (overconfidence) in the future success of the current idea. Although beliefs dominated by overconfidence/underconfidence are consistent over time, beliefs dominated by projection bias are inconsistent, depending on whether the researcher obtains a new idea. Projection bias implies that

[1] As described later, we assume that examining the current idea is costly and time-consuming. In our model, the researcher obtains the outcome of the examination with certainty, although the value of it is uncertain. Thus, we can also interpret the examination as publishing the research outcomes.

[2] Herrera and Hörner (2013) consider this problem in a social learning model.

[3] Some studies focusing on possible biases that immediately come to mind are, for example, Loewenstein, O'Donoghue, and Rabin (2003) on projection bias, Dubra (2004) on overconfidence, and O'Donoghue and Rabin (1999) on procrastination.

a person tends to think that others know what s/he knows but do not know what s/he does not know. This suggests that, before coming up with an idea, projection bias makes researchers think that other researchers have not come up with it. By contrast, after the researcher comes up with an idea, s/he tends to believe that others would come up with it. This implies ex-ante optimism and ex-post pessimism around a research idea regarding its uniqueness.

By building a search model, we show that a researcher with projection bias is more likely to discard the current idea and explore a new one than a researcher with overconfidence or underconfidence. This result comes from the combination of ex-ante optimism and ex-post pessimism. While ex-post pessimism reduces the expected value of exploiting a current idea, ex-ante optimism increases the value of exploring new ideas. As a result, the researcher becomes selective: s/he hesitates to move on to the next stage to examine the current idea and keeps looking for a new idea. By contrast, optimism and pessimism due to overconfidence and underconfidence do not necessarily make the researcher selective. This occurs because overconfidence enhances the perceived value of both exploiting the current idea and exploring a new one. Consequently, a researcher with projection bias is more likely to change ideas frequently compared to an overconfident researcher. We have the same result in the case of underconfidence, although underconfidence has the opposite impact on the perceived value of exploiting the current idea and exploring a new one.

Our results have implications for the file drawer problem. On the one hand, projection bias does not reduce the motivation to explore a new idea because the researcher is ex-ante optimistic. This projection bias effect mitigates the file drawer problem. On the other hand, since the researcher is ex-post pessimistic, projection bias prevents the researcher from examining the current idea. This makes the file drawer problem more serious. This trade-off determines whether projection bias mitigates or exacerbates this problem. Furthermore, we show that researchers with higher performance are more likely to have a projection bias when the required value of the research outcome for success is sufficiently large. Previous studies suggest that projection bias generally reduces communication to share background information about research because people with projection bias consider such information to be well-known (e.g., Madarász, 2012). These findings explain that in a high-performing group, researchers with projection bias tend to conduct their research with scarce communication to share information with others. When less communication promotes projection bias, its impact of projection bias on the file drawer problem becomes significant, whether positive or negative.

This study broadly relates to the literature on experimentation and learning.[4] Our contribution to the literature is an elucidation of the effects of projection bias in experimentation. In our model, projection bias shifts beliefs about a rival's knowledge from before to after having an idea.[5] We investigate how such a shift in belief influences a player's decision by developing a parsimonious search model in which a player decides whether to examine an existing idea or explore a new idea.

One of our main findings is that projection bias makes researchers selective. Building an ordinal search model, Dubra (2004) focuses on overconfidence and shows a similar result: overconfidence makes a player search longer. Except that the main concern is not projection bias but overconfidence, a difference from our research is that Dubra (2004) assumes no uncertainty in the current value of stopping the search, which leads to the result that overconfidence does not affect the current value. By contrast, our model includes uncertainty about the value of stopping the search (i.e., examines the current idea). Thus, overconfidence influences the expected value of stopping a search. Consequently, in our model, overconfidence does not necessarily make the researcher search longer, which differs from projection bias.

As another relevant study, Auster, Che, and Mierendorff (forthcoming) considers the choice between two alternatives with uncertain values and builds a bandit model with ambiguity. They show that a player with ambiguity aversion is more likely to conduct short searches in earlier periods but tends to conduct longer searches in later periods. Despite differences in modeling, our extended study has a similar result in the sense that behavioral bias affects seemingly contradictory ways:

[4] See, for example, Hörner and Skrzypacz (2017) for a survey of the literature and references therein.

[5] We consider interpersonal projection bias on whether others have the same idea (knowledge). Following a seminal paper, Loewenstein, O'Donoghue, and Rabin (2003), many studies have applied the notion of projection bias to various situations, depending on what and how people project, such as intrapersonal projection by Kaufmann (2022), information projection by Madarász (2012, 2021) and Madarász, Danz, and Wang (2023), and taste projection by Gagnon-Bartsch (2016), Gagnon-Bartsch, Pagnozzi, and Rosato (2021), Gagnon-Bartsch and Rosato (2022), and Bushong and Gagnon-Bartsch (forthcoming).

when introducing the process of choosing a research area in our model, we show that projection bias makes the researcher less likely to change the area but more likely to change the idea.

2 Model

The researcher plans to decide on research ideas in infinite periods. In each period, the researcher comes up with a new research idea at a cost of $k > 0$.[6] After arriving at an idea, the researcher receives a signal $s \in \mathbb{R}$, which correlates with the true value of the outcome when executing the idea. The value of the outcome is $v \in \mathbb{R}$ that is ex-ante uncertain and distributed by the cumulative distribution function (CDF) F.[7] The distribution of signal s depends on the true value v. $G(\cdot \mid v)$ denotes the CDF of the signal. We assume that all CDFs have full support on $\mathbb{R}$. Let f and g be the probability distribution functions of F and G, respectively. We assume that F and G are twice continuously differentiable for all variables. We also assume that, for each $v > v'$, $G(\cdot \mid v)$ dominates $G(\cdot \mid v')$ in the sense of the monotone likelihood-ratio.[8] To obtain the outcome of the idea, the researcher must devote one period to examining it at a cost $c > 0$. After receiving the signal, the researcher must decide whether to examine the current idea or explore a new one in the next period (Figure 1). In the next period of the examination of the previous idea, the researcher explores a new idea at a cost of k. The researcher can also quit his/her research work; we normalize the value of quitting to 0. Finally, let $\delta \in (0, 1)$ be a discount factor.

Any idea that the researcher comes up with may have been examined by another researcher. We refer to such a previous researcher as a *precursor*. We assume that for each idea, with probability $p \in [0, 1]$, a precursor has come up with the idea before the researcher. When the precursor comes up with an idea, s/he decides whether to examine it. If the precursor examines the idea, s/he gains the outcome, which is publicly known.[9] For simplicity, we assume that the precursor makes a

[6] One of the most parsimonious examples is an economist looking for ideas for a new study.

[7] Instead of gaining value v directly, we allow the researcher to gain utility $u(v)$, where u is monotone.

[8] $\frac{g(s|v)}{g(s|v')}$ is increasing in s. In other words, $\frac{\partial^2 \ln(g(s|v))}{\partial s \partial v} > 0$.

[9] We can also interpret the precursor's action as the decision to examine the idea and publish the outcome. Even if publication is costly, not being published implies lower v, and then the main results can be held. We provide a way to extend our main model to elaborate a publication process in section A of Supplementary Materials.

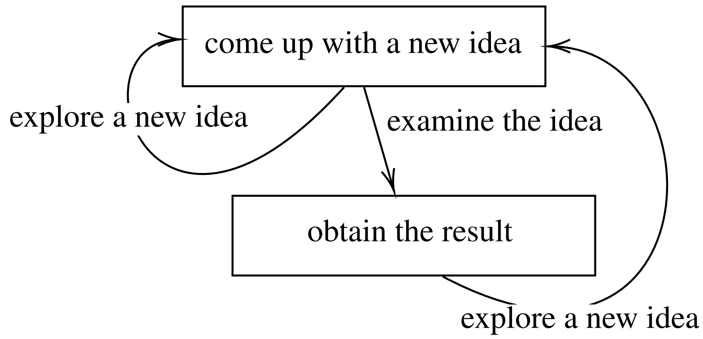

Figure 1: Decision Flow

single-period decision, which is independent of the researcher's decision.

As for the probability that a precursor previously came up with the idea, a researcher can have a misbelief. We examine the following three kinds of misbelief.

- *Consistent misestimation*: The researcher believes that the probability is $\rho \neq p$.

- *Naïve projection*: Before the researcher comes up with the idea, s/he believes that the probability is $p^- < p$. After coming up with it, s/he believes that the probability is $p^+ > p$. On the timing before coming up with the idea, the researcher believes that even after coming up with it, the probability s/he believes is p^-.

- *Sophisticated projection*: The researcher rationally expects his/her belief to shift over time. More precisely, the sophisticated researcher has the same bias as the naïve one, but even before coming up with the idea, s/he realizes that the future self decides based on their updated belief after it has occurred.[10]

We refer to the researcher with each type of behavioral bias as a consistent, naïve, and sophisticated researcher, respectively.

Consistent misestimation indicates that a researcher has consistent overconfidence/underconfidence in the uniqueness or innovativeness of his/her idea. For example, when $\rho < p$, the researcher

[10]If the person also realizes the change of his/her belief and perceives it, then it is a special case of consistent misestimation with $\rho = p^+$.

underestimates the probability of others coming up with the idea, implying that the researcher is overconfident in his/her idea.

Projection bias indicates a researcher's tendency to believe that others know what s/he knows and do not know what s/he does not. In this model, the research idea indicates a kind of knowledge. While researchers believe that other researchers do not have an idea before obtaining it, they believe that others have an idea after obtaining it.[11] Thus, the researcher's belief about whether others have the idea inconsistently changes before and after s/he obtains it. Specifically, we formulate a researcher with projection bias as follows. When the degree of projection bias is represented by $\alpha \in (0, 1)$, the researcher's belief is $p^I = (1-\alpha)p + \alpha I$. $I \in \{0, 1\}$ represents whether the researcher has an idea. When the researcher has an idea $I = 0$, and when s/he do not have an idea, $I = 1$. Thus, $p^- = (1-\alpha)p$ and $p^+ = (1-\alpha)p + \alpha$ are the researcher's beliefs before and after coming up with an idea, respectively. Note that a naïve researcher does not understand that his/her belief will change after obtaining an idea. By contrast, a sophisticated researcher understands such a change in his/her belief. The sophisticated researcher then solves an intrapersonal game with his/her future selves.

3 Analysis

3.1 Deciding Whether to Explore or Exploit Ideas

We first analyze the precursor's decision. We assume that the precursor has no other precursor. When the precursor receives the signal s, the condition under which s/he examines the idea is

$$\int vh(v \mid s)dv - c > 0,$$

[11]This study focuses on the situation in which a researcher cares whether others have found the same information. As another way of formulating projection bias, a researcher projects his/her received signal toward others' signals. We briefly analyze this case in section B of Supplementary Materials.

where

$$h(v \mid s) = \frac{g(s \mid v) f(v)}{\int g(s \mid v') f(v') dv'}.$$

It is known that $h(\cdot \mid s)$ monotone likelihood ratio dominates $h(\cdot \mid s')$ if and only if $s > s'$. This implies that $V(s) := \int v h(v \mid s) dv$ increases in s. The precursor examines the idea if and only if $s > s^*$, where $V(s^*) = c$.

We consider a consistent researcher's decision. Let the researcher's belief in the probability that a precursor comes up with the idea be ϱ. Given that the outcome of the examination is not publicly known and that the researcher receives the signal s, the expected value of v is

$$V^*(s \mid \varrho) := \frac{\int v dv \varphi_\varrho(v \mid s)}{\int dv \varphi_\varrho(v \mid s)},$$

where

$$\begin{aligned} \varphi_\varrho(v \mid s) &:= f(v) \left[\varrho G(s^* \mid v) + (1 - \varrho)\right] g(s \mid v) \\ &= f(v)[1 - \varrho(1 - G(s^* \mid v))] g(s \mid v). \end{aligned}$$

Note that $\varrho G(s^* \mid v) + (1 - \varrho)$ is the probability that a precursor had come up with the idea but it was not examined, or no precursor came up with it, on the condition that the true value of the idea is v. From the monotone likelihood ratio dominance property of G, we have the following lemma:[12]

Lemma 1. *$V^*(s \mid \varrho)$ decreases in ϱ and increases in s.*

Using V^*, we consider the decision to examine the current idea or explore a new one. Let $\bar{V}$ be the value of coming up with an idea that is endogenized below. Given the belief ϱ for the *future*

[12] Appendix provides proofs of Lemmata 1 and 2, and Proposition 1.

idea, the Bellman equation is

$$\bar{V} = \delta \int_{s^*_\varrho(\bar{V})} dsg(s)[\overbrace{V^*(s \mid \varrho) - c}^{\text{EU of examination}} + \delta \cdot (\bar{V} - k)] + \underbrace{G(s^*_\varrho(\bar{V}))}_{\text{prob. of exploration}} \cdot \delta \cdot (\bar{V} - k) \tag{1}$$

where $G(s) = \int dvf(v)G(s \mid v)$ and $s^*_\varrho(\bar{V})$ is the cut-off value for examining the current idea or exploring a new one.

Given the value of exploring a new idea, the cutoff value with belief ϱ for the *current* idea is defined such that

$$\begin{aligned} \delta \cdot \left[V^*(s^*_\varrho(\bar{V}) \mid \varrho) - c + \delta \cdot (\bar{V} - k)\right] &= \delta \cdot (\bar{V} - k) \\ \Rightarrow V^*(s^*_\varrho(\bar{V}) \mid \varrho) &= (1 - \delta) \cdot (\bar{V} - k) + c. \end{aligned} \tag{2}$$

From lemma 1, $s^*_\varrho(\bar{V})$ increases in ϱ and $\bar{V}$. This implies the following lemma.

Lemma 2. *When $\bar{V}$ is the solution to* (1) *and* (2)*, $\bar{V}$ decreases in ϱ.*

Let $\bar{V}(\varrho)$ be the solutions to (1) and (2). From the values of $\bar{V}(\varrho)$ and s^*_ϱ, we characterize the decision to examine the current idea or explore a new one. Finally, because the utility of quitting the research is 0, the researcher quits if and only if $\bar{V}(\varrho) < k$. In summary, because the researcher's belief is consistent in every period $\varrho = \rho$, s/he examines the idea if $s > s^*_\rho(\bar{V}(\rho))$ and $\bar{V}(\rho) > k$. If $\bar{V}(\rho) > k$ but $s < s^*_\rho(\bar{V}(\rho))$, they explore a new idea.

Next, consider the naïve researcher. When the naïve researcher decides to examine the current idea, s/he believes that $\varrho = p^+$ because s/he already knows the idea. By contrast, when s/he explores a new idea after discarding the current idea, the belief about the probability is $\varrho = p^-$, which determines the value $\bar{V}$, because s/he does not have ideas before exploration. The researcher then examines the idea if and only if $s > s^*_{p^+}(\bar{V}(p^-))$ and $s > s^*_{p^+}(\bar{V}(p^-))$ and $\bar{V}(p^-) > k$. If $\bar{V}(p^-) > k$ but $s < s^*_{p^+}(\bar{V}(p^-))$, s/he explores a new idea. If $\bar{V}(p^-) < k$, s/he quits research.

Finally, the sophisticated researcher anticipates that his/her belief will be updated to p^+ once s/he finds an idea. By contrast, because his/her belief in the precursor is p^-, the value function is

$$\bar{V} = \delta \int_{s^*_{p^+}(\bar{V})} dsg(s) \left[V^*(s \mid p^-) - c + \delta \cdot (\bar{V} - k)\right] + G(s^*_{p^+}(\bar{V})) \cdot \delta \cdot (\bar{V} - k). \tag{3}$$

Note that $s^*_{p^+}$ satisfies $V^*(s^*_{\varrho}(\bar{V}) \mid \varrho) = (1 - \delta) \cdot (\bar{V} - k) + c$ (solution to (2) at $\varrho = p^+$). This comes from the assumption that a sophisticated researcher anticipates that his/her future decision on examination will be made by the future self, who has the belief p^+.

Based on these results, we have the following proposition:

Proposition 1. *The naïve researcher is more likely to explore a new idea, and not more likely to quit than any consistent researcher with $\rho \in [p^-, p^+]$ or sophisticated researcher.*

The intuition is as follows. As the naïve researcher believes that his/her idea is more likely to be unique, s/he is optimistic about exploring a new idea that brings higher value. By contrast, the researcher is pessimistic about the current idea, as s/he believes that it would be examined in the past. Thus, s/he is more motivated to explore new ideas. Furthermore, optimism about the future value of exploring new ideas prevents the researcher from quitting his/her research work. By contrast, if the researcher is sophisticated, s/he rationally expects his/her future pessimism, which motivates her/him to quit the research.[13]

Concerning which type of researcher can succeed, our results suggest that the naïve researcher is more likely to survive (i.e., less likely to quit) due to his/her optimism. To investigate this, consider the case in which researchers who yield values higher than a threshold (i.e., $v \geqslant X \in \mathbb{R}$) succeed (e.g., win a prize).[14] In comparison with the consistent researcher with ρ, the difference occurs when the drawn signal s satisfies $s^*_{\rho}(\bar{V}(\rho)) < s < s^*_{p^+}(\bar{V}(p^-))$ because these researchers make the same decision for the remaining cases. With this signal, while the consistent researcher examines the idea, the naïve researcher explores a new idea. Let $q(s^*)$ be the probability that a

[13] As mentioned in footnote 11, if we consider projection bias regarding signals, bias works the opposite way. Consequently, although a researcher is selective when the degree of bias is low, its effect is ambiguous when the degree is high.

[14] To include the gain from the success, we can modify the utility as $u(v) = \beta \cdot \chi(v \geqslant X) + (1 - \beta) \cdot v$ for some $\beta \in (0, 1)$. Because only the monotonicity of u is crucial for the previous results, this modification does not affect the main results. Here, $\chi(E) = 1$ if E is true and 0 otherwise.

researcher with a cut-off value s^* examines the idea, and $r(s^*)$ be the conditional probability that the examined idea yields $v \geqslant X$. Suppose that once $v \geqslant X$, the researcher gains 1. Subsequently, the expected value W is

$$W = q(s^*) \cdot \delta \cdot [r(s^*) + (1 - r(s^*)) \cdot \delta W] + \delta \cdot (1 - q(s^*)) \cdot W$$
$$\Rightarrow W(s^*) = \frac{\delta \cdot q(s^*) \cdot r(s^*)}{1 - \delta \cdot [1 - \delta \cdot (1 - r(s^*)) \cdot q(s^*)]}.$$

By interpreting $1 - \delta$ as the exogenous probability of quitting the research, W is the probability of success. For a researcher with a cut-off value s^*,

$$q(s^*) = 1 - G(s^*)$$
$$r(s^*) = \frac{\int_{s^*} ds \int_X dv \varphi_p(v \mid s)}{\int_{s^*} ds \int dv \varphi_p(v \mid s)}.$$

Then, q is higher, but r is lower for the consistent researcher with ρ.

Suppose $\lim_{v \to \infty} g(s \mid v)/g(s' \mid v) = 0$ for each $s < s'$. Subsequetly, at the limit $X \to \infty$, $r_i(s)/r_i(s') \to 0$ for each $s < s'$. This implies $W(s^*_{p^+}(\bar{V}_{p^-})) > W(s^*_\rho(\bar{V}_\rho))$. Hence, W is greater for the naïve researcher.

Corollary 1. *Suppose that* $\lim_{v \to \infty} g(s \mid v)/g(s' \mid v) = 0$ *for each* $s < s'$. *When* X *is sufficiently large, the probability that the researcher succeeds is greater when s/he has a naïve projection bias.*

Corollary 1 implies that higher-performance researchers are more likely to have projection bias when the required value of the research outcome for success is sufficiently large. We can interpret this result as indicating that when projection bias reduces communication (e.g., Madarász, 2012), researchers with projection bias tend to conduct their research with less communication with others in a high-performing group.

3.2 Extention for Exploring a New Idea

Thus far, we have assumed that researchers can find an idea with certainty if they explore it at cost. To elaborate on the exploration process, we now assume that a researcher decides on the research field and explores new research ideas in the chosen field. Because this exploration process can be built as an ordinal bandit model, the researcher changes his/her field if there are no ideas after a certain amount of time (cutoff). The exploration is a continuous Poisson process. The research field is suited to the researcher or not.[15] If the research field is suitable, the researcher comes up with an idea with probability $\lambda \cdot dt$ within period dt; otherwise, s/he cannot. The ex-ante probability of the research field being suitable is $\pi \in (0, 1)$. Exploring an idea for period dt costs the researcher $k \cdot dt$. After arriving at an idea, as in the main model, the researcher chooses whether to consume one period to examine the idea or explore a new one. Furthermore, the researcher can change his/her research field at any time at a fixed cost of K. The discount rate is denoted by r and $e^{-r} = \delta$.

Now, consider the researcher's decision-making. Let π_t be the belief that the current research field is suitable in period t. Once the idea is arrived, $\pi_t = 1$. Then, if the value of coming up with an idea is $\bar{V}$,

$$\begin{aligned} \bar{V} &= \lambda dt \bar{V} - dtk + (1 - \lambda dt)(1 - rdt)\bar{V} \\ &\Rightarrow \bar{V} = \frac{\lambda \bar{V} - k}{\lambda + r}. \end{aligned}$$

Using this, given the belief ϱ, the Bellman equation is

$$\bar{V} = \delta \int_{s^*_\varrho(\bar{V})} dsg(s) \left[\overbrace{V^*(s \mid \varrho) - c}^{\text{EU of investigation}} + \delta \cdot \frac{\lambda \bar{V} - k}{\lambda + r} \right] + \underbrace{G(s^*_\varrho(\bar{V}))}_{\text{prob. of exploration}} \cdot \delta \cdot \frac{\lambda \bar{V} - k}{\lambda + r} \tag{4}$$

[15] This assumption is to make the exploring process meaningful.

where $G(s) = \int dv f(v) G(s \mid v)$ and $s_{\varrho}^{*}(\bar{V})$ is the cut-off value which is defined such that

$$\delta\left[V^{*}(s_{\varrho}^{*}(\bar{V}) \mid \varrho) - c + \delta\frac{\lambda\bar{V} - k}{\lambda + r}\right] = \delta\frac{\lambda\bar{V} - k}{\lambda + r}$$
$$\Rightarrow V^{*}(s_{\varrho}^{*}(\bar{V}) \mid \varrho) = (1 - \delta)\frac{\lambda\bar{V} - k}{\lambda + r} + c.$$

The value $\bar{V}$ is almost the same as that in the main model and the properties shown in Proposition 1 hold true in this case.

Thus, the value of exploration is

$$V(\pi_t) = \pi_t \lambda dt \cdot \bar{V}(\varrho) - dtk + [\pi_t(1 - \lambda dt) + (1 - \pi_t)](1 - rdt)V(\pi_{t+dt}), \tag{5}$$

and that of changing the field is $V(\pi) - K$. Note that $\dot{\pi}_t = -\pi_t(1 - \pi_t)\lambda$. As this is an ordinal exponential bandit problem (e.g., Keller, Rady, and Cripps, 2005), there is a cutoff $\bar{\pi}$ such that if $\pi_t < \bar{\pi}$, the researcher changes the field. Solving (5) and $V(1) = \bar{V}$, we obtain

$$V(\pi') = \frac{\lambda\pi' r\bar{V}(\varrho) - k(r + \lambda(1 - \pi'))}{r(\lambda + r)},$$

for each $\pi' \in [0, 1]$, and $V(\pi) - K = V(\bar{\pi})$. We can verify that $V'(\pi') > 0$ for each $\pi' \in [0, 1]$, thus proving that $\bar{\pi}$ increases if $\bar{V}(\varrho)$ increases.

The naïve researcher considers $\varrho = p^{-}$ and $\bar{V}(\varrho)$ is decreasing in ϱ, the cut-off $\bar{\pi}$ is smaller than that of any consistent researcher with $\rho \geqslant p^{-}$. We have the following proposition.

Proposition 2. *The naïve researcher is less likely to change his/her field than any consistent researcher with $\rho \geqslant p^{-}$.*

Proposition 2 implies that projection bias provides different attitudes toward selecting the ideas to be examined and research fields: the researchers are indecisive about selecting ideas but persistent in selecting fields. Such attitudes may seem contradictory from the perspective of the behavior of "changes what they work on."[16] However, such attitudes can also be interpreted as deliberating

[16]The coexistence of similar contradictory attitudes is shown in other research. For example, as mentioned in

on research ideas to produce high-quality outcomes in a single research field.

4 Conclusion

This study considers a researcher facing a trade-off between exploiting the current research idea and exploring a new one in infinite periods. The researcher faces uncertainty about the value of the current idea and believes that other researchers may have already come up with the same idea. By developing a search model, we show that researchers with projection bias are more likely to be selective than those with overconfidence/underconfidence, which implies that the former more often discard the current idea and explore a new one than the latter do. Moreover, in our extended model, which introduces the process of choosing a research area, we show that projection bias makes the researcher less likely to change his/her area but more likely to change ideas.

The driving force that causes projection bias to work differently from other biases is the uncertainty in the uniqueness of the idea, which arises from the file drawer problem. This problem makes researchers unconfident, and they become selective and demotivated to conduct research. We show that projection bias affects the file drawer problem in two ways. From an ex-ante perspective, the researcher's willingness to conduct research increases as projection bias makes the researcher optimistic. However, in the ex-post view, because projection bias makes the researcher pessimistic, the researcher becomes more selective in his/her ideas that can be examined. The tension between the conflicting effects of projection bias influences researchers' decisions and performance.

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Appendix: Proofs

Proof of Lemma 1. First, we note that $\frac{\varphi_\varrho(v|s)}{\varphi_\varrho(v|s')} = \frac{g(s|v)}{g(s'|v)}$ increases in v if and only if $s > s'$ by the monotone likelihood ratio dominance property of g.

Similarly, we show the following properties.

Claim 1. $\frac{\varphi_\varrho(v|s)}{\varphi_{\varrho'}(v|s)}$ *increases in v if and only if $\varrho' > \varrho$.*

Proof of Claim 1. By definition,

$$\frac{\varphi_\varrho(v \mid s)}{\varphi_{\varrho'}(v \mid s)} = \frac{1 - \varrho \cdot (1 - G(s^* \mid v))}{1 - \varrho' \cdot (1 - G(s^* \mid v))}.$$

Then, $\frac{\varphi_\varrho(v|s)}{\varphi_{\varrho'}(v|s)}$ increases in v if and only if

$$-\frac{\partial G(s^* \mid v)}{\partial v}(\varrho' - \varrho) > 0.$$

As the monotone likelihood-ratio dominance implies first-order stochastic dominance, $G_v(s^* \mid v) < 0$. Therefore, $\frac{\varphi_\varrho(v|s)}{\varphi_{\varrho'}(v|s)}$ increases in v if and only if $\varrho' > \varrho$. □

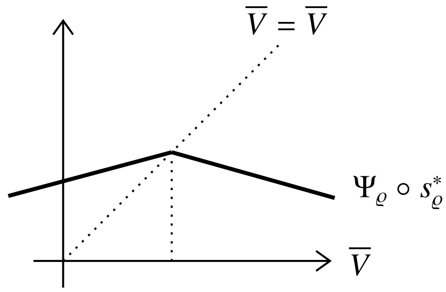

Figure 2: Graph of Ψ

This implies the monotone likelihood ratio property of φ for smaller ϱ and higher s. Then, the statement immediately follows from its first-order stochastic dominance property. □

Proof of Lemma 2. Let $\Psi_\varrho(s^*)$ be a function that

$$\Psi_\varrho(s^*) := \frac{\delta \int_{s^*} dsg(s)\left[V^*(s \mid \varrho) - c\right] - k\left[\delta^2 + \delta(1-\delta)G(s^*)\right]}{1 - \delta^2 - \delta(1-\delta)G(s^*)}.$$

Then, when $\bar{V} = \Psi_\varrho(s_\varrho^*(\bar{V}))$, the Bellman equation (1) holds. We show a property of $\Psi_\varrho(s^*)$.

Claim 2. *When* (2) *holds,* $\Psi_\varrho'(s^*) > 0$ *if and only if* $\bar{V} < \Psi_\varrho(s^*)$ *at* $s^* = s_\varrho^*(\bar{V})$.

Proof of Claim 2. By differentiating $\Psi_\varrho(s^*)$ with respect to s^*, $\Psi_\varrho'(s^*) > 0$ if and only if

$$\begin{gathered}[\delta(V^*(s^* \mid \varrho) - c) + k\delta(1-\delta)](1 - \delta^2 - \delta(1-\delta)G(s^*)) < \\ (1-\delta)\delta\left[\delta \int_{s^*} dsg(s)\left[V^*(s \mid \varrho) - c\right] - k\left[\delta^2 + \delta(1-\delta)G(s^*)\right]\right].\end{gathered}$$

From (2), at $s^* = s_\varrho^*(\bar{V})$, the inequality above is equivalent to $\bar{V} < \Psi_\varrho(s^*)$. □

As $s_\varrho^*(\bar{V})$ increases in $\bar{V}$, the shape of $\Psi_\varrho(s_\varrho^*(\bar{V}))$ is drawn as shown in Figure 2. This shows the uniqueness of the solution to $\bar{V} = \Psi_\varrho(s_\varrho^*(\bar{V}))$. Note that as $V^*(\cdot \mid \varrho)$ is decreasing in ϱ, $\Psi_\varrho(\cdot)$ decreases in ϱ. Then, the total differentiation and the fact $\Psi_\varrho'(s^*) = 0$ at $s^* = s_\varrho^*(\bar{V})$ show that $\bar{V}$ also decreases in ϱ. □

Proof of Proposition 1. First, we compare a naïve researcher with a consistent researcher. From

Lemma 2, $\bar{V}(p^-) \geqslant \bar{V}(\rho)$ for any $\rho \in [p^-, p^+]$. As $s^*_\varrho(\bar{V})$ increases in ϱ and $\bar{V}$, $s^*_{p^+}(\bar{V}(p^-)) > s^*_\rho(\bar{V}(\rho))$ for any $\rho \in [p^-, p^+]$.

Next, we compare the naïve researcher with a sophisticated researcher. Let $\bar{V}^{\text{so}}(p^-)$ be the solution of (3) and (2) at $\varrho = p^+$. This value is less than $\bar{V}(p^-)$ because $s^* = s^*_+(\bar{V})$ is not the optimal cut-off value for a researcher with belief p^-. This also implies that $s^*_{p^+}(\bar{V}(p^-)) > s^*_{p^+}(\bar{V}^{\text{so}}(p^-))$; therefore, the cut-off value is lower for sophisticated researchers. □

Supplementary Materials for

At the Crossroad of Research: The Impact of Projection Bias on the Decision to Explore or Exploit Ideas

Kohei Daido and Tomoya Tajika

A Publication Process

In the main model, we assume that any outcome of the examination becomes public. We can modify the model to include the publication process, such that the outcome is published if and only if $v \geqslant Y$. In this case, the value of the examination is

$$V^*(s \mid \varrho) := \frac{\int v dv \varphi_\varrho^Y(v \mid s)}{\int dv \varphi_\varrho^Y(v \mid s)},$$

where

$$\begin{aligned}\varphi_\varrho^Y(v \mid s) &:= f(v)\left[\varrho[G(s^* \mid v) + (1 - G(s^* \mid v))\chi(v < Y)] + (1 - \varrho)\right] g(s \mid v)\\ &= f(v)\left[1 - \varrho(1 - G(s^* \mid v))\chi(v \geqslant Y)\right] g(s \mid v).\end{aligned}$$

Then, $\frac{\varphi_\varrho^Y(v|s)}{\varphi_{\varrho'}^Y(v|s)}$ increases in v if and only if

$$-\left[\frac{\partial G(s^* \mid v)}{\partial v}\chi(v \geqslant Y) - (1 - G(s^* \mid v))\frac{\partial \chi(v \geqslant Y)}{\partial v}\right](\varrho' - \varrho) > 0.$$

As in the proof of Claim 2, $\frac{\varphi_\varrho^Y(v|s)}{\varphi_{\varrho'}^Y(v|s)}$ increases in v if and only if $\varrho' > \varrho$. Therefore, the results of the main model are confirmed as valid.

B Projection on Signals

This section assumes that a researcher believes, with probability α, that the precursor obtains the same signal.

We consider the probability that the precursor did not examine the outcome in the researcher's belief, which is calculated as follows:

$$\varphi_{\varrho,\alpha}(v \mid s) \coloneqq f(v)\left[(1-\alpha)[1-\varrho(1-G(s^* \mid v))] + \alpha Z\right] g(s \mid v),$$

where

$$Z = \begin{cases} 1-\varrho & \text{if} \quad s \geqslant s^* \\ 1 & \text{if} \quad s < s^*. \end{cases}$$

That is,

$$\varphi_{\varrho,\alpha}(v \mid s) = \begin{cases} [1-\varrho(1-(1-\alpha)G(s^* \mid v))]g(s \mid v) & \text{if} \quad s \geqslant s^* \\ [1-(1-\alpha)\varrho(1-G(s^* \mid v))]g(s \mid v) & \text{if} \quad s < s^*. \end{cases}$$

Similar to the discussion in Claim 2, we show that $\varphi_{\varrho,\alpha}(\cdot \mid s)/\varphi_{\varrho,\alpha'}(\cdot \mid s)$ increases in v if and only if

$$\rho(\alpha'-\alpha)\frac{\partial G(s^* \mid v)}{\partial v} > 0 \iff \alpha > \alpha'.$$

Therefore, $\varphi_{\varrho,\alpha}(\cdot \mid s)$ monotone likelihood ratio dominates others with a lower α. This implies that the value of the examination increases in α.

Note that because the projection bias works after receiving a signal, a reduction in the value of the examination also occurs after receiving the signal. As explained in the main model, this makes it less likely for researchers to explore new ideas. Subsequently, the projection bias on the received signal weakens the tendency of the researcher to be selective.

Similarly, we consider the case in which $\varrho = p(1-\alpha)+\alpha$. In this case, $\varphi_{\varrho,\alpha}(\cdot \mid s)$ monotone likelihood ratio dominates $\varphi_{\varrho',\alpha'}(\cdot \mid s)$ if

$$\omega(\alpha) \coloneqq ((1-\alpha)p+\alpha)(1-\alpha) < ((1-\alpha')p+\alpha')(1-\alpha').$$

Therefore, the maximizers of $\omega(\alpha)$, $\alpha^* = \max\{\frac{1-2p}{2(1-p)}, 0\}$ are most likely selective for the same $\bar{V}$.

For $\bar{V}$, projection bias on the signal does not work because the signal cannot be received before coming up with an idea. Then, the value of $\bar{V}$ remains $\bar{V}(p^-)$.

In summary, the selectiveness (the size of the cutoff) increases in α if $\alpha < \alpha^*$; however, if $\alpha > \alpha^*$, the effect becomes ambiguous as the value of the changing idea $\bar{V}(p^-)$ also increases in α.