Universitat Autònoma de Barcelona

ESSAYS ON INDUSTRIAL ORGANIZATION

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Essays on Industrial Organization

Doctoral Thesis

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Contents

Introduction

This thesis comprises three chapters addressing different research questions on industrial organization inspired and motivated by real-world issues in the organization of science, the innovation process, and the consequences on the market competition of the presence of consumers with non-standard preferences.

The first chapter, *"Performance Evaluation and Collaboration Matching between Industry and Academic,"* was motivated by the interest in understanding the research partnership between pharmaceutical firms and academics in the development of new drugs. COVID-19 has highlighted the importance of collaboration in developing new curative principles once more. Partnerships between pharmaceutical companies and academic institutions are becoming widespread for the development of new pharmaceutical drugs with curative value and hence commercial potential.

In this chapter, I study industry-science alliances, using the partnership between pharmaceutical companies and academics as a motivating example. I am interested in understanding the collaboration pattern when the following two key factors are present. First, there is no complete alignment of the participants' (firm's and academic's) objectives nor perfect monitoring of the academic's research effort on the collaborative project. For instance, drug development is a long-term process, of which the final product is usually obtained after several years. However, a failed drug in the market or a failure at phase III clinical trial could cause hundreds of millions of dollars lost for the pharmaceutical companies. The primary firm's decision is whether to continue with the very costly trials once it observes the first results about the effectiveness of the drug. Therefore, in this setup and in the real world, the firms always use the evaluation at the interim stage on the proof-of-concept developed by the academic in their project to decide whether to resume or abandon this collaborative project. Moreover, the remuneration or the financial support to the academics also depends on this evaluation.

To investigate the characteristics of the partnerships formed between firms and academics, I use a two-sided matching model. Clearly, firms are more eager to work with distinguished academics. This results in the firms competing for more productive academics in the collaboration market: a typical two-sided competitive matching market. For instance, one company collaborates with an academic on a pharmaceutical project, referred to as one-to-one matching. In this model, the equilibrium consists of a menu of incentive contracts and matching between firms and academics. In the analysis, I consider different scenarios of evaluation technologies for the firms and show the implications of the evaluation features on the equilibrium matching. I show that given a certain structure of evaluation techniques, the equilibrium matching is unique and can be positive assortative (PAM: the better firms form partnerships with the better academics) or negative assortative (NAM: the worse firms collaborate with the better academics). Moreover, the results also show that even though the more productive academics receive the higher utility levels in equilibrium, their remuneration could be lower than the worse academics. This is because she is matched with a lower-paid company, and motivating her to exert a sufficient effort does not require a higher payoff.

As introduced above, this chapter is written with pharmaceutical collaborations in mind since this was the initial framework to formulate the research questions of this chapter. However, the results can also apply to other environments, such as the matching between venture capitalists and startups, and may shed light on the observation of different collaboration patterns.

In chapter 2, *"The Impact of Consumers' Regret on Firms' Decisions in a Durable Good Market,"* I investigate the interaction between the competition in the innovative product market and the consumers' non-standard preference. In particular, the model considers a two-period durable good market, with an incumbent selling its good in both periods and an entrant that will introduce an improved version in the second period. Usually, the model assumes the consumers' information and understanding of the entrant's innovative product are limited. This implies that they could not be perfectly informed about the valuation of the entrant's product when deciding whether to buy the incumbent's product in period one or wait for period two and then choose which version to buy.

This chapter considers the consumers' non-standard preference because they may experience regret (i.e., a prevalent unpleasant emotion for many individuals). Consumers usually anticipate the possible ex-post regret of choosing one product over the other, influencing their purchase decisions. The consumers would experience *action regret* (regret having bought the incumbent's product) if they bought the incumbent's version in the first period and afterward realized that they appreciated the entrant's version more. They would experience *inaction regret* (regret not having bought the incumbent's goods) if they waited for the new version and realized that they did not enjoy the entrant's goods.

This second chapter analyzes price formation, purchase decisions, and how, when, and which firms may profit from consumers' anticipated regret. The analysis allows discussing the consequences of regret on the market equilibrium and when firms would prefer to remind consumers about their potential regret.

The last chapter of my thesis, *"Similar-to-me effects in the grant application process: Applicants, panelists, and the likelihood of obtaining funds,"* is joint work with Albert Banal-Estañol, Inés Macho-Stadler, and David Pérez-Castrillo, where we empirically study whether the characteristics of grant-evaluation panels affect the applicants' likelihood of obtaining funding. In particular, we are especially interested in studying if particular types of panels favor particular types of applicants.

Using the award decisions of the UK's Engineering and Physical Sciences Research Council (EPSRC), we show that not only the applicants' but also the panels' characteristics matter. Panels of higher quality, in terms of prior research performance, for instance, as well panels that include more female members or members of Asian origin, are tougher than others. Our main results indicate that panel members tend to favor more (or penalize less) applicants with similar characteristics to them, as the similar-to-me hypothesis suggests. We show, for instance, that the quality of the applicants (regarding the past research records) is more critical for panels of high quality than for panels of relatively lower quality, that basic oriented panels tend to penalize applied-oriented applicants, and that panels with less female members tend to penalize teams with more female applicants.

The chapters of my thesis do not have a common topic or a common methodology. The first two chapters are theoretical, while the third is empirical. As for the topic, the first and the last chapter are related to science and innovation, while the second considers market competition and price formation. Moreover, the first chapter considers standards preferences, while the second and the third include behavioral preferences (regret and similar-to-me effects). These characteristics of my thesis represent my aspiration to understand different industrial organization issues, my interest in theoretical and empirical approaches, and my belief that non-standard preferences may help to understand some of the stylized facts we observe.

Chapter 1

Performance Evaluation and Collaboration Matching between Industry and Academic

1.1 Introduction

Pharmaceutical companies frequently engage in research collaborations with universities. In the biotech sector this collaboration has proved to be crucial for the development of new therapeutic compounds.[1] There are numerous examples of collaborative agreements, such as the partnership of the pharmaceutical group Chiesi with the University of Alberta to investigate the behavior of aerosol particles in the humid lung environment. In Japan, Takeda Pharmaceutical Company collaborates with Kyoto University, and Chugai Pharmaceutical collaborates with Osaka University on drug development projects (see, e.g., Kuwashima, 2018).

[1]In bioscience, many new drugs are based on discovery-based R&D efforts, which the academic partners can produce more efficiently. Mansfield (1998) illustrates the importance of the products that have been developed with the substantial aid of academic research. Rafols et al. (2014) and Palmer and Chaguturu (2017) stress that many pharmaceutical companies outsource their own research departments to the academics because this is more efficient and less costly. Hughes (2008) and Tralau-Stewart et al. (2009) show that the collaborations between pharmaceutical companies and academic institutions increase the efficiency of the development of new drugs.

In these collaborative agreements, the industry partners aim at generating new information and ground-breaking ideas which ultimately result in marketable products. However, the partnerships face two important challenges. First, the contribution of the academics is subject to moral hazard. Since their effort is difficult to monitor, academic researchers may be more concerned about reinforcing their scientific reputation than to align their agenda to that of the pharmaceutical partner. They may concentrate on the research value of a project instead of its commercial value.[2] Second, developing meaningful therapeutic product is an extremely complex process. To profitably market a new product, there is a lengthy and uncertain process that requires a lot of work and resources, which is often too long and costly for the interests of industry partners.[3] The possible commercial outcome is not available in the short run, thus, academics cannot wait to get paid in the far future. After the academic develops some proof-of-concept results, pharma partners evaluate the future prospects of the compounds, the significance of the gains and losses at stake, consider a possible change in plans, and pay for the academic.[4] This evaluation allows the pharmaceutical company to have more information to decide whether to abandon the project, if at this interim stage there is evidence showing that the likelihood of a successful outcome is not high enough.[5] The pharma evaluation about the prospects of the proof-of-concept also helps to motivate the academic.

In this paper, I formalize the research collaboration between pharma compa-

[2]See, for instance, Kloyer (2011), Kloyer and Scholderer (2012), and Hillerbrand and Werker (2019). Academics and companies may have conflicts of interest, e.g., because the industry is profit-oriented while the academic's goal is the production of knowledge.

[3]DiMasi et al. (2003) state that developing a new drug costs on average 1.3 billion dollars and takes 14 years. Pammolli et al. (2011) show that R&D investments tend to focus on new therapeutic targets characterized by high uncertainty and difficulty.

[4]Henstock (2019) emphasizes that the application of artificial intelligence helps the pharma company to predict the toxicology and even the clinical outcomes according to the cumulative data in the company.

[5]Amgen, Novartis, and Banner Alzheimer's Institute halted the investigation of the drug umibecestat when they received disappointing early data from a pre-planned analysis. Merck was no longer supporting the development of the oral formulation of the drug vernakalant for the prevention of atrial-fibrillation recurrence based on Merck's "assessment of the regulatory environment and projected development timeline." The project may be discontinued if the expectation of very negative side effects is high, the risk of not marketing the new drug are important, or the pharmaceutical company anticipates significant reputational and monetary losses. Huss (2016) shows that companies who experience a failed trial often face a plummeting stock price, and need to reduce workforce, close research sites and consolidate business units, and potentially sell off various therapeutic areas to preserve the core business.

nies and academics as an agency problem, where each company in the market hires one academic through an incentive contract to work on the project. The academic's effort influences the profitability of finding some meaningful results and is subject to moral hazard. At an interim stage, the pharma company conducts an evaluation of the preliminary results. This evaluation provides a signal that the company uses to decide whether to abandon the project if the prospects are negative, and to motivate the academic to provide enough effort.

The collaborations between the pharma companies and academics for obtaining new drugs are numerous and widespread (Chin-Dusting et al., 2005), but the literature studying them is still scarce. To further understand these partnerships, I model the collaborative agreements in a market, where pharma companies compete for academics. In the market, the pharma companies are characterized by their evaluation ability, and academics differ in their effort productivity. The competition in the market implies that the characteristics of the collaboration patterns, the contract signed in each collaborative agreement, and the utility levels obtained by the participants are all endogenous. I study which pharma company collaborates with which academic in the market, the contract they sign, and when the company will choose to abandon the project.

My analysis considers different types of evaluation technology for the pharma companies, and investigates how they affect the equilibrium outcome. I begin by considering an evaluation technology such that all pharma companies have the same probability of getting the bad signal when the prospects are bad, while if the future outcome is good, companies will receive a good signal with heterogeneous probability. That is, companies make type I errors with different probability but they make type II errors with the same likelihood. I refer to this scenario as *sensitivity* case. Second, I study the scenario where companies are heterogeneous in making type II errors but they make type I error with the same probability. I call this scenario *specificity*.[6] Finally, I present the results in the scenario where what-

[6]Sensitivity and specificity are statistical terms describing the accuracy of a diagnostic test, where the positive result is bad news and the negative one is good news. Sensitivity measures how well a test can identify true positives and specificity measures how well a test can identify true

ever the future outcome is, the pharma companies receive a noisy signal (either positive or negative). In this case, a company makes both type I and type II errors with the same probability, and firms are heterogeneous in this probability. I name this case *symmetry*.

An equilibrium outcome is a situation where there is no company and no academic that can form a new partnership that is more beneficial for both of them (i.e., there is no blocking pair). I analyze the characteristics of the equilibrium outcome in the three markets, using the method in Legros and Newman (2007) and Chade et al. (2017).

I prove that, in all scenarios, the pharma companies always terminate the project when they receive a signal suggesting that the chances of failure are high. More importantly, I also find that in each market, there is a unique collaboration pattern between pharma companies and academics (i.e., a unique type of matching). In the first type of evaluation technology, the sensitivity case, pharma companies with better evaluation technologies, which make fewer type I error, collaborate with more productive academics (the matching is positive assortative). In the other two scenarios, specificity and symmetry, better pharma companies, which make fewer errors, collaborate with the less productive academics (the matching is negative assortative). In all cases, I explain the intuition that lead to these different conclusions. Roughly, it depends on whether the additional benefit from hiring a good academics is higher for a company with a good or a bad evaluation technology.[7]

In addition, I am interested in understanding the relationship between the academic's productivity and her equilibrium remuneration. I show that, in all scenarios, a more productive academic may obtain lower remuneration than a less productive one. This is because a more productive academic needs less incentives to provide the effort required by the company. On the other hand, the company hiring the better academic will pay her a lower bonus in case of receiving a positive report

negatives.

[7]However, there is no purely complementary or substitutable relationship between the firm's and the academic's characteristics, which can easily imply PAM or NAM because of non-fully transferable utility. I will show this property later in the Section 2.

from the evaluation. Besides, a more productive academic is more desirable in the market, which yields a greater competition for her. This competition has a positive effect on the academic's payment. However, the two former negative impacts may dominate the positive competition effect, which implies that a lower payment for a better academic.

This paper is related to different strands of the literature. It is related to the principal-agent models where the outcome of the relationship is not observable and it cannot be used in the contract to motivate the agent. With a non-contractual outcome, the pharma company has to acquire extra information or to monitor the agent in order to motivate her to exert effort. Chade and Kovrijnykh (2016) consider a related question. They study a repeated model hazard problem between a principal and an agent (an isolated relationship), where the outcome of the principal's project is not observable. The principal hires an agent to explore information about the outcome, which provides either a positive or a negative signal realization. Then, the principal decides whether to exercise the option at hand or continue searching in the next period. The authors find that the agent may be rewarded for delivering bad news from the evaluation. In contrast, in my paper, the value of the project depends on the effort of the agent and the information acquisition is conducted by the pharma company. Moreover, I consider a static setup instead of a dynamic one, and the endogenous formation of partnership in the market instead of an isolated relationship.

Second, this paper is related to the literature on sorting with non-fully transferable utility. Legros and Newman (2007) provide the generalized differences (GD) condition as the sufficient condition for monotone matching. Chade et al. (2017) propose the single-crossing (SC) condition to identify the monotonicity of the matching as a new version of GD condition. After obtaining the equilibrium contract in my model, I adopt the SC condition to analyze the characteristics of the equilibrium matching in the market.

My paper is also a part of a recent, growing literature that investigates two-sided matching markets under moral hazard with non-fully transferable utility.

This literature has been very useful to understand different market organizations. For example, Alonso-Paulí and Pérez-Castrillo (2012) discuss a market where the shareholder may offer an incentive contract or a contract including a Code of Best Practice. They find that the matching is positively assortative if all the participants sign the same type of contract but it is not necessary PAM if both types of contracts coexist in equilibrium. Antón and Dam (2020) analyze the incentive contract under double-sided moral hazard and the market equilibrium between investors with heterogeneous monitoring ability and entrepreneurs with heterogeneous collateral values. They find a negative assortative matching between them, and show that owing to this matching, there is a general non-monotonic association between the loan rate and the collateral.[8]

To the best of my knowledge, this paper is the first attempt to take the firm's performance evaluation, its continuation decision of collaborative project into account to investigate the internal contract and the endogenous matching problems about the partnership between pharmaceutical companies and academics.

The rest of the paper is organized as follows. In Section 2, I present the model. Section 3 states the equilibrium outcome in each scenario. Section 4 extends and discusses the results. Section 5 concludes the paper.

1.2 Model

This section introduces the model, the details of the market, and the method I use to identify the equilibrium matching in this market.

[8]Other papers combining agency theory and sorting in two-sided matching market with non-fully transferable utility are Dam and Pérez-Castrillo (2006), Altinok (2020) and Hong et al. (2020) (see, Macho-Stadler and Pérez-Castrillo, 2018, for a review of the literature about incentives and matching). Papers investigating sorting in a market with moral hazard when the utility is fully transferable are, for example, Ghatak and Karaivanov (2014) and Serfes (2005) (see, Macho-Stadler and Pérez-Castrillo, 2020, for more details).

1.2.1 Model setup and timing of game

I consider a two-sided matching market where each participant is involved in at most one transaction. There are a continuum of pharmaceutical companies P and a continuum of academics A. A pharma company is denoted by p, p_i, $p_{i'}$, etc., and an academic is denoted by a, a_j, $a_{j'}$, etc. All the participants are risk-neutral, and the academics are protected by limited liability: an academic's payoff has to be non-negative in any event. A collaboration involves one pharma company and one academic, which is denoted by the pair (p_i, a_j).

I begin by focusing on a particular pair (p_i, a_j), and introducing the nature of the collaborative project, the pharma company's and the academic's characteristics, their contributions to the project, and the timing of the game. Then I will introduce the details of matching market.

If pair (p_i, a_j) is formed, the participants sign a contract, and academic a_j supplies an effort to develop the project of pharma company p_i. The eventual result of the project will take place in the far future (e.g., a new drug development always takes six to ten years on average, which leads to a non-contractual outcome). Both the effort of a_j and the outcome are not verifiable. Hence, the asymmetric information about the effort results in a moral hazard problem, and the incentives cannot be based on the outcome.

I assume that at an interim stage, p_i gets information from an evaluation procedure that allows the company to decide whether to continue or to abandon the project. If the project is abandoned, the revenue for the company is zero; if the project is continued, it can give one of two outcomes in the future: either a success or a failure. Therefore, the project's outcome depends on both the academic's effort and the company's continuation decision of the project.

Formally, if the partnership (p_i, a_j) is formed, at the first stage, a_j exerts a non-contractual and non-observable effort e_j, associated with a cost $c(e_j) = \frac{1}{2}e_j^2$. Then, as a consequence of the effort, the project has a certain prospect. Since the effort is not observable and outcome is not contractual, p_i obtains information by applying a test (an evaluation process) on the project afterwards. The result of this test is used to reduce the academics' moral hazard, and with this information, p_i decides whether to continue the project. To understand this decision, let me explain the process with more details.

If the project is continued, it delivers either a success, which yields a good outcome $G > 0$ or a failure, which yields a loss $B < 0$. The project's prior probability of success is determined by the academic's effort e_j, and takes the form:

$$\pi(G) = \gamma_j e_j, \ \pi(B) = 1 - \gamma_j e_j,$$

where γ_j denotes the productivity of academic a_j, which is common knowledge.[9] Academics are heterogeneous in terms of their productivity, which is distributed on the interval $[\underline{\gamma}_j, \bar{\gamma}_j]$, with $\underline{\gamma}_j \geq 0$. The higher the productivity parameter γ_j, the better academic a_j.

I assume that in the case of failure, the loss is significant; if the project fails, the loss is larger than the benefit when it succeeds (i.e., $|B| \geq G$).[10] This allows me to concentrate on the case where the failure of the project is damaging to the pharmaceutical company. For instance, Huss (2016) discuss the high loss of a failure, which is even more important than the benefit from the success for many pharmaceutical companies.

When the company evaluates the prospect of the project, the issue of the evaluation takes the form of a signal, s, with two possible realizations: good (g) or bad (b), i.e., $s \in \{g, b\}$. The signal is correlated with the final outcome as follows:

$$\pi(g|G) = \alpha_i; \quad \pi(b|G) = 1 - \alpha_i;$$

$$\pi(b|B) = \beta_i; \quad \pi(g|B) = 1 - \beta_i,$$

[9]The academic's ability (productivity) in a research topic can be assessed by the number of patents she has, her academic reputation, or her publication record. This information is publicly available.

[10]In Section 4, I discuss how the results extend for the cases where G and $|B|$ do not satisfy $G \leq |B|$.

where α_i (respectively, β_i) denotes the accuracy of the evaluation system when the outcome will be a success (failure). For example, α_i represents the likelihood of receiving the good signal g if the future outcome will be successful.

Companies are heterogeneous in their evaluation technology (α_i, β_i), with $\alpha_i \in [0,1]$ and $\beta_i \in [0,1]$, with $(\alpha_i + \beta_i) \geq 1$. Although the evaluation technology is characterized by these two parameters, I restrict attention to uni-dimensional heterogeneity owing to the restriction of the method of identifying market equilibrium (that I will introduce later). Thus, I consider that pharma p_i's "type", t_i, can take three possible forms: $t_i \in \{(\alpha_i, \beta), (\alpha, \beta_i), (\alpha_i, \beta_i = \alpha_i)\}$. I refer to the first market as *sensitivity* setup, because pharma companies differ in the likelihood of receiving the signal g if the future outcome will be a success but they are homogeneous in receiving the signal b if the future outcome is a failure. The second situation, to which I call *specificity* setup, is the other way around. In this scenario, companies in the market differ in the likelihood of receiving the signal b if the future outcome is a failure, but they all receive the signal g with the same probability if the future outcome is success. Finally, the last market, where the likelihood of receiving g when the future outcome is success and b when it is failure coincide and differ among companies, is the *symmetry* scenario. In my model, the pharma company's type t_i is public information, and it measures its experience in developing medical products.

The signal s allows the pharma company to motivate the academic, to update its belief (using the Bayes' rule), and to decide whether to abandon the project if the chances of suffering the loss from failure ($B < 0$) in the future are high.

Given that the only verifiable and observable element is the signal s, the contract only depends on the realization of this signal; that is, the compensation scheme $W_{ij} = (w^g_{ij}, w^b_{ij})$ is based on two payoffs: w^g_{ij} is the payment to academic a_j if the signal is g, and w^b_{ij} is the wage if signal b is received.

The timing of the game is the following: (1) In a one-to-one matching market, pharma companies, identified by their characteristic t_i, compete for academics identified by their productivity γ_j through the incentive contract W_{ij}. (2) When a matched partnership is formed, the academic exerts a non-observable effort e_j to construct a project; (3) The pharma company tests the prospects of the project, and receives a signal $s \in \{g,b\}$; (4) According to the signal realization, the pharma company decides whether to abandon the project, and makes the payment established in the contract to the academic. (5) The company receives the outcome in the far future if the project is continued. I solve the model by backward induction.

1.2.2 Participants' utilities and decisions in a partnership for a given contract

Let us consider that (p_i,a_j) have signed the contract $W_{ij} = (w^g_{ij}, w^b_{ij})$. First, let me introduce the academic's expected utility. It depends on the contract W_{ij}, and the probabilities of the different signal realizations. Let $\pi(g)$ and $\pi(b)$ be the probability of receiving a good signal and that of a bad signal, respectively:

$$\pi(g) = \alpha_i \gamma_j e_j + (1-\beta_i)(1-\gamma_j e_j)$$
$$\pi(b) = 1 - \alpha_i \gamma_j e_j - (1-\beta_i)(1-\gamma_j e_j).$$

I denote $Eu_j(W_{ij}, e_j; p_i)$ academic a_j's expected utility for any effort e_j when she is matched to pharma p_i under the contract W_{ij}. Formally:

$$\begin{aligned} Eu_j(W_{ij}, e_j; p_i) &= \pi(g) w^g_{ij} + \pi(b) w^b_{ij} - \frac{1}{2} e_j^2 \\ &= [\alpha_i \gamma_j e_j + (1-\beta_i)(1-\gamma_j e_j)] w^g_{ij} + \\ &\quad [1 - \alpha_i \gamma_j e_j - (1-\beta_i)(1-\gamma_j e_j)] w^b_{ij} - \frac{1}{2} e_j^2 \end{aligned}$$

Given the contract W_{ij} that academic a_j signed with pharma p_i, she chooses the optimal effort $e_j(W_{ij}; p_i)$, which maximizes her expected utility. The incentive compatibility constraint is:

$$e_j(W_{ij}; p_i) = \arg\max_{e_j} Eu_j(W_{ij}, e_j; p_i) = (\alpha_i + \beta_i - 1)\gamma_j (w^g_{ij} - w^b_{ij}). \qquad (ICC)$$

As expected, the optimal effort increases in the first term of the contract $W_{ij} = (w^g_{ij}, w^b_{ij})$ and decreases in the second one. It also increases in the pharma's and the academic's ability $(\alpha_i, \beta_i, \gamma_j)$.

Before introducing the company's expected profit, I discuss its decision at the project continuation stage under different signal realizations. This decision depends on the probability of a good outcome when the signal g is revealed, that I denote by $\pi(G|g)$. This posterior is obtained by Bayes' rule. The probabilities $\pi(G|b)$, $\pi(B|b)$, and $\pi(B|g)$ are other posteriors computed by Bayes' rule. Note that these posteriors depend on the characteristics of the partners and on the academic's effort via the contract.

To simplify the explanation, consider that signal s is more informative for the corresponding outcome, i.e., $\pi(G|g) \geq \pi(G|b)$ and $\pi(B|b) \geq \pi(B|g)$.[11] In this case, if p_i abandons the project under g, it also stops it under b since b indicates a failure with a higher likelihood. As a consequence, the relationship would no be profitable. Since only profitable relationships could be formed in equilibrium, that is, at least those relationships in which the pharma company p_i continues the project when signal g is revealed could be formed. Otherwise, the pharma always abandon the project whatever the signal is, the partnership should not be started at the beginning. Therefore, the pharma company only decides to continue the project or not when receiving a bad signal b.

The company 's expected profit Ev_i under different continuation decisions when the signal b reveals are:
(i) when pharma p_i discontinues the project, its ex-ante expected profit $E\hat{v}_i$ is defined by:

$$E\hat{v}_i(W_{ij}; a_j) = \quad \pi(g)[\pi(G|g)G + \pi(B|g)B - w^g_{ij}] + \pi(b)[0 - w^b_{ij}],$$

[11]This relationship between the posteriors is always satisfied under the initial assumption $(\alpha_i + \beta_i) > 1$

(ii) when pharma p_i continues of the project, its expected profit is $E\tilde{v}_i$ defined by:

$$E\tilde{v}_i(W_{ij};a_j) = \quad \pi(g)[\pi(G|g)G + \pi(B|g)B - w_{ij}^g] + \pi(b)[\pi(G|b)G + \pi(B|b)B - w_{ij}^b].$$

Note that given a pair (p_i, a_j), all probabilities and the expected profit in two alternatives are determined by the contract.

The pharma chooses the continuation decision that yields a higher expected profit, denote $Ev_i(W_{ij};a_j) = \max\{E\hat{v}_i(W_{ij};a_j),\ E\tilde{v}_i(W_{ij};a_j)\}$.

The contract signed by (p_i, a_j) must be acceptable to both of them. I assume that the academic has zero utility when she does not accept any contract from the pharma on the other side of the market. Then, a contract $W_{ij} = (w_{ij}^g, w_{ij}^b)$ is acceptable to academic a_j if she is better off than rejecting any collaboration:

$$Eu_j(W_{ij};p_i) \geq 0. \qquad (ACC_a)$$

On the other hand, an acceptable contract for the pharma company p_i has to give positive profit:

$$Ev_i(W_{ij};a_j) \geq 0. \qquad (ACC_p)$$

Besides, the academic is protected by limited liability (the wages are non-negative):

$$w_{ij}^g, w_{ij}^b \geq 0. \qquad (LLC)$$

Definition 1.1. *A contract W_{ij} for a pair (p_i, a_j) is feasible if it satisfies: (1) the wages are non-negative (LLC); (2) the contract is acceptable to both p_i and a_j (ACC_a and ACC_p).*

The incentive contract for a pair (p_i, a_j) should satisfy the feasibility stated in Definition 1.1. Otherwise, the pharma company and the academic will not form a collaboration.

1.2.3 Competition and stability in the market

In the two-sided matching market that I analyze, there are a set of companies and a set of academics. Pharma companies compete for academics via the incentive contract. The competition and the contract's design are simultaneous. I first define the matching between the pharma companies and the academics.

Definition 1.2. *A one-to-one matching is a mapping $\mu : P \cup A \to P \cup A$ such that (1) $\mu(p_i) \in A \cup \{p_i\}$, for all $p_i \in P$; (2) $\mu(a_j) \in P \cup \{a_j\}$, for all $a_j \in A$; (3) for any pair $(p_i, a_j) \in P \times A$, $\mu(p_i) = a_j$ if and only if $\mu(a_j) = p_i$.*[12]

The outcome of the game is a market allocation $(\mu, \mathscr{W})$. It consists of a matching μ and a menu of contracts $\mathscr{W}$, which contains the feasible contract W_{ij} between each matched pair $(p_i, a_j) \in P \times A$. In equilibrium, a pair (p_i, a_j) is "divorce-free," which means that if one participant could find other potential partner before signing the contract such that both of them are better off under this new partnership, then they would form the new partnership. Thus, the matching is endogenous. The solution concept I use is stability:

Definition 1.3. *The market allocation $(\mu, \mathscr{W})$ is stable if there is no blocking pair (p_i, a_j) and a feasible contract W_{ij} such that $Ev_i(W_{ij}; a_j) \geq Ev_i(W_{i\mu(i)}; \mu(p_i))$ and $Eu_j(W_{ij}; p_i) \geq Eu_j(W_{\mu(j)j}; \mu(a_j))$, with at least one strict inequality.*

In the market, when pharma p_i competes for academic a_j, to design the optimal contract for a_j, it has to consider the expected utility a_j can obtain from its potential competitors (i.e., other companies in the market). Let $\underline{U}_j$ represent this reservation utility of academic a_j. This $\underline{U}_j$ will be the equilibrium reservation utility under the competition, which is endogenous. In consequence, pharma p_i must offer at least $\underline{U}_j$ to academic a_j. In the relationship (p_i, a_j), the feasible contract with endogenous reservation utility is denoted by $W_{ij}(\underline{U}_j)$. Thus, a_j's participation constraint is:

$$Eu_j(W_{ij}(\underline{U}_j); p_i) \geq \underline{U}_j. \qquad (PC)$$

[12] In the following sections, depending on which one is more convenient, when (p_i, a_j) are matched under μ, then I will use interchangeably the following expressions: $\mu(p_i) = a_j$, $\mu(\alpha_i) = \gamma_j$, $\mu(\beta_i) = \gamma_j$, and $\mu(i) = j$. If the individual stays unmatched, then $\mu(p_i) = p_i$ or $\mu(a_j) = a_j$.

Note that, for any $\underline{U}_j$, (PC) dominates the (ACC_a). In addition, the contract for any matched pair (p_i, a_j) in the stable market allocation should be Pareto optimal. That is, in equilibrium there is no matched (p_i, a_j) such that both participants can sign an alternative feasible contract to be better off.

I am particularly interested in studying whether the equilibrium matching μ is positive or negative assortative. In other words, I will analyze whether the better company may be matched with the better academic (the matching is positive assortative) or the other way around (negative assortative).[13] Formally:

Definition 1.4. *A matching μ is positive assortative (PAM) if $\gamma_{\mu(i)} \geq \gamma_{\mu(i')}$ for any two matched pharma companies p_i and $p_{i'}$ with $t_i \geq t_{i'}$. Similarly, a matching μ is negative assortative (NAM) if $\gamma_{\mu(i)} \leq \gamma_{\mu(i')}$ for any two matched pharma companies p_i and $p_{i'}$ with $t_i \geq t_{i'}$.*

Note that the utility is not fully transferable in my model because of the limited liability and the moral hazard. To identify the equilibrium matching, I adopt the single-crossing (SC) condition provided by Chade et al. (2017) presented as the other version of generalized differences (GD) condition in Legros and Newman (2007). Regardless of the participants' distribution, the single-crossing condition is based on the following marginal rate of substitution:

$$MRS_i = -\frac{\partial E v_i(W_{ij}(\underline{U}_j); a_j)/\partial \gamma_j}{\partial E v_i(W_{ij}(\underline{U}_j); a_j)/\partial \underline{U}_j}.$$

This MRS_i represents that for a given level of the company's expected profit, the utility that it is willing to provide for per unit increase in academic's productivity. If the MRS increases in the pharma's ability t_i, the equilibrium matching in the stable market allocation is PAM, and if the reverse case holds, then it is NAM. Let me explain the intuition behind this general result using a two-by-two example as illustrated in Figure 1.1.

Let's consider a situation where the SC condition holds. In the space of reser-

[13] A matching could be neither positive or negative assortative. But this is not the case in this paper.

vation utilities and abilities of the academics, Figure 1.1 represents the pharmas' iso-profit curves.[14] Consider two pharma companies p_i, $p_{i'}$ with $t_i > t_{i'}$ and two academics a_j, $a_{j'}$ with $\gamma_j > \gamma_{j'}$. In the case illustrated in the figure, the iso-profit curves are flatter for pharma $p_{i'}$ and the iso-profits of the firms cross once at point x. The worse pharma, $p_{i'}$, obtains the same level of expected profit, $Ev_{i'}$, at point x hiring academic $a_{j'}$ and at point y hiring academic a_j. As Figure 1.1 shows, since pharma p_i has steeper iso-profit curves, it can profit more from hiring academic a_j, and can offer this academic a higher expected utility (illustrated by the point z).

In equilibrium, the worse pharma $p_{i'}$ will hire $a_{j'}$ and obtain profit $Ev_{i'}$, and it has no incentive to increase the utility provided to a_j since it is not profitable. Pharma p_i hires academic a_j. In this case, $MRS_i > MRS_{i'}$, and the matching is PAM. The reverse case would appear if pharma p_i has flatter iso-profit curves, then using a similar argument we would conclude that the matching is NAM.

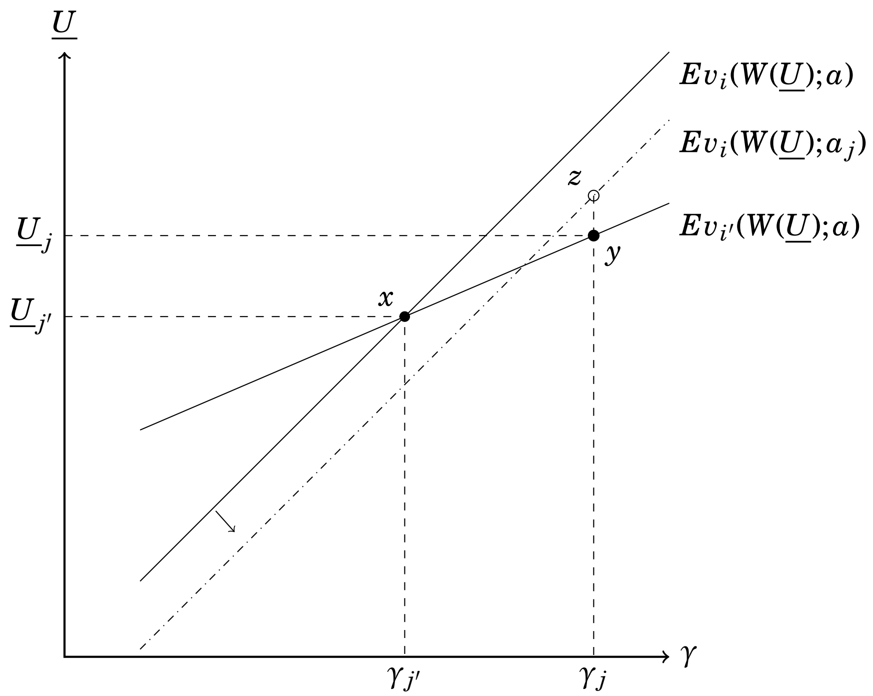


Figure 1.1: Illustration of the SC condition.

In my model, where companies' and academics' types are continuous, the SC condition can be formalized as follows:

[14] One can imagine that there are many iso-profit curves, but I only take three of them to explain the intuition.

Definition 1.5. ***Single-Crossing (SC) Condition***, *Chade et al. (2017):*
The matching is PAM (NAM) if

$$SC = \frac{\partial MRS_i}{\partial t_i} = \frac{\partial^2 Ev_i}{\partial t_i \partial \gamma_j} - \frac{\partial Ev_i/\partial \gamma_j}{\partial Ev_i/\partial \underline{U}_j} \frac{\partial^2 Ev_i}{\partial t_i \partial \underline{U}_j} \geq (\leq) 0.^{15}$$

To adopt the SC condition approach, the companies' characteristics must be the same form and one-dimensional. That is, all companies must have the same structure of the evaluation technology. This is the reason for the simplification introduced in the markets I will consider. As announced, I will concentrate on the three setups: sensitivity, specificity, and symmetry setups in turn.[16] For completeness, I will discuss a particular two-by-two case where the companies have different evaluation technology as one extension.

In this paper, I assume that the firm has all the bargaining power, thus, the contract in the market equilibrium maximizes its expected profit which ensures the academic at least $\underline{U}_j$. If the academic has all the bargaining power, she will obtain the highest utility from her partner pharma, and this pharma will earn zero expected profit. Note that single-crossing condition is for any level of endogenous utility $\underline{U}_j$, which is acceptable to both pharma and academic. Thus, if the level of $\underline{U}_j$ does not influence the characteristics of stable matching in the market equilibrium, then this means that the bargaining power will not affect the matching.

1.3 Stable market allocations under moral hazard

In this section, I investigate the stable market allocation $(\mu, \mathscr{W})$ in three different market scenarios. In all of them the population of academics differ on the productivity parameter γ_j. On the other hand, I consider a population of pharma companies have the following the evaluation technology t_i in different scenarios:

[15]Note that if $SC = 0$, any matching is an equilibrium matching.

[16]If the firm has multiple heterogeneity, we can consider that there exists correlation between the firm's characteristics. In such a way, we can still reduce the multiple heterogeneity to the one-dimensional heterogeneity.

(1) Sensitivity: $t_i = (\alpha_i, \beta)$ with $\alpha_i \in [\underline{\alpha}_i, \bar{\alpha}_i]$, and β is fixed, for all $p_i \in P$.

(2) Specificity: $t_i = (\alpha, \beta_i)$ with $\beta_i \in [\underline{\beta}_i, \bar{\beta}_i]$, and α is fixed, for all $p_i \in P$.

(3) Symmetry: $t_i = (\alpha_i, \beta_i = \alpha_i)$ with $\alpha_i \in [\underline{\alpha}_i, \bar{\alpha}_i]$, for all $p_i \in P$.

In each market, I proceed in the following way. First, for any possible pair (p_i, a_j), I solve for the equilibrium contract $W_{ij}(\underline{U}_j)$ as a function of the endogenous reservation utility $\underline{U}_j$, and obtain the profit of the company and the utility of the academic under moral hazard. Second, I compute the *MRS* between the profit of the pharma company and the utility of the academic, and apply the SC condition to learn the characteristics of the equilibrium matching. I also discuss why companies and academics are matched in such a way.

1.3.1 Sensitivity scenario: $\pi(g|G) = \alpha_i$, $\pi(b|B) = \beta$

Consider the market where pharma companies are heterogeneous in making type I errors but homogeneous in making type II errors. This may be the case for companies that the data about the serious side effects of compounds are public such that they have the same chances to make errors when the project is a failure in the future. Therefore, the company's information structure has the following form:

$$\pi(g|G) = \alpha_i, \quad \pi(b|G) = 1 - \alpha_i;$$
$$\pi(b|B) = \beta, \quad \pi(g|B) = 1 - \beta.$$

I include one assumption to guarantee that the equilibrium effort is not too high so that the probabilities are always well defined.

Assumption 1.1. $[G\bar{\alpha}_i - (1-\beta)B]\bar{\gamma}_j^2 \leq 1$.

Assumption 1.1 guarantees the interior solution in equilibrium, i.e., $\pi(G) = \gamma_j e_j \in [0,1]$.

The equilibrium contract

For any pair (p_i, a_j), when designing the payment scheme $W_{ij}(\underline{U}_j) = (w^g_{ij}, w^b_{ij})$ pharma company p_i maximizes its expected profit subject to the constraints PC and LLC. It also takes into account the ICC, which in this case is:

$$e_j(W_{ij}(\underline{U}_j); p_i) = (\alpha_i + \beta - 1)\gamma_j(w^g_{ij} - w^b_{ij}).$$

After receiving the bad signal from the evaluation, the pharma company can decide to continue or to abandon the project, and this determines the company's expected profit and hence the optimal contract. I will consider these two possibilities when solving for the equilibrium, but to discuss some important characteristics of the equilibrium contract, let me assume for a moment that the company abandons the project when a bad signal reveals.

The ICC implies that w^g_{ij} is higher than w^b_{ij}. Moreover, the company prefers to increase w^g_{ij} and reduce w^b_{ij} to zero (because of the limited liability constraint) to make the contract more profitable. As it is common in moral hazard problems with a risk neutral academic protected by limited liability, the equilibrium contract is influenced by the reservation utility. Depending on the reservation utility level $\underline{U}_j$, there are three possibilities. First, if $\underline{U}_j$ is low enough, the company is compelled to pay a bonus w^g_{ij} to induce the academic to exert a sufficient effort. In this case, the equilibrium contract does not depend on $\underline{U}_j$. The company can make the highest profit, and the academic earns an expected utility higher than $\underline{U}_j$, i.e., the participation constraint is not binding.

Second, for a higher level of $\underline{U}_j$, the company has to increase w^g_{ij} such that the equilibrium contract ensures the academic's reservation utility, i.e., the participation constraint is binding, $Eu_j = \underline{U}_j$. The threshold of $\underline{U}_j$, which separates these two possibilities, depends on the characteristics of the company and the academic (α_i and γ_j). I denote this threshold by $\hat{U}(\alpha_i, \gamma_j)$. To simplify the expressions I use

$X_{ij} = [G\alpha_i - B(1-\beta)](\alpha_i + \beta - 1)\gamma_j{}^2$. Formally,

$$\hat{U}(\alpha_i, \gamma_j) = \frac{(X_{ij} + 3(1-\beta))(X_{ij} - (1-\beta))}{8(\alpha_i + \beta - 1)^2 \gamma_j{}^2}.$$

Third, if $\underline{U}_j$ is extremely high, no contract between p_i and a_j is acceptable to the company since no contract is profitable. Let $\tilde{U}(\alpha_i, \gamma_j)$ denote the threshold above which pharma p_i prefers not to form a partnership with a_j:

$$\tilde{U}(\alpha_i, \gamma_j) = \frac{[X_{ij} + (1-\beta) + \sqrt{(X_{ij} - (1-\beta))^2 + 4(\alpha_i + \beta - 1)^2 \gamma_j{}^2 (1-\beta) B}]^2 - 4(1-\beta)^2}{8(\alpha_i + \beta - 1)^2 \gamma_j{}^2}.$$

Proposition 1.1 formally presents the optimal contract. One of the characteristics of the equilibrium is that pharma companies always abandon the project when the signal is bad. Let me add another notation $Y_{ij} = \sqrt{(1-\beta)^2 + 2(\alpha_i + \beta - 1)^2 \gamma_j{}^2 Eu_j}$ to simplify expressions, where Eu_j is the academic's expected utility.

Proposition 1.1. *Consider the sensitivity scenario. In a stable market allocation* $(\mu, \mathscr{W})$*, for any matched pair* (p_i, a_j) *and any equilibrium reservation utility* $\underline{U}_j \leq \tilde{U}(\alpha_i, \gamma_j)$*, the equilibrium contract* $\mathrm{W}_{ij}(\underline{U}_j)$ *satisfies:*

a) the academic's expected utility is $Eu_j = max\{\hat{U}(\alpha_i, \gamma_j), \underline{U}_j\}$*;*

b) the payment scheme is $\mathrm{W}_{ij}(\underline{U}_j) = (w_{ij}^g = \frac{Y_{ij} - (1-\beta)}{(\alpha_i + \beta - 1)^2 \gamma_j{}^2},\ w_{ij}^b = 0)$*;*

c) the academic's optimal effort is $e_j(\mathrm{W}_{ij}(\underline{U}_j); p_i) = \frac{Y_{ij} - (1-\beta)}{(\alpha_i + \beta - 1)\gamma_j}$*;*

d) the company abandons the project when receiving a bad signal b;

e) the company's expected profit is $Ev_i(\mathrm{W}_{ij}(\underline{U}_j); a_j) = \frac{(X_{ij} - Y_{ij})(Y_{ij} - (1-\beta))}{(\alpha_i + \beta - 1)^2 \gamma_j{}^2} + B(1-\beta)$

In equilibrium the company discontinues the project when a bad signal b reveals. In this scenario, with sensitivity evaluation technology, the company anticipates that a bad signal b often indicates a failure $B < 0$ with a high likelihood, such that it profits more from abandoning the project when receiving a bad signal.

The company's expected profit as a function of the endogenous reservation utility $\underline{U}_j$ is illustrated by Figure 1.2. When the reservation utility satisfies $\underline{U}_j \leq \hat{U}(\alpha_i, \gamma_j)$, the optimal contract $W_{ij}(\underline{U}_j)$ does not depend on $\underline{U}_j$; the contracts are the same for any $\underline{U}_j \leq \hat{U}(\alpha_i, \gamma_j)$. It ensures academic a_j the same expected utility $Eu_j = \hat{U}(\alpha_i, \gamma_j) \geq \underline{U}_j$. One can see $\hat{U}(\beta_i, \gamma_j)$ as the lowest utility that academic a_j can obtain from company p_i while the company obtains the highest profit, which is presented by the flat profit line in Figure 1.2.

If $\underline{U}_j > \hat{U}(\alpha_i, \gamma_j)$, the company provides the academic stronger incentives because it needs to offer the academic a higher utility level than before. Then the company's expected profit is lower, as shown by Figure 1.2.

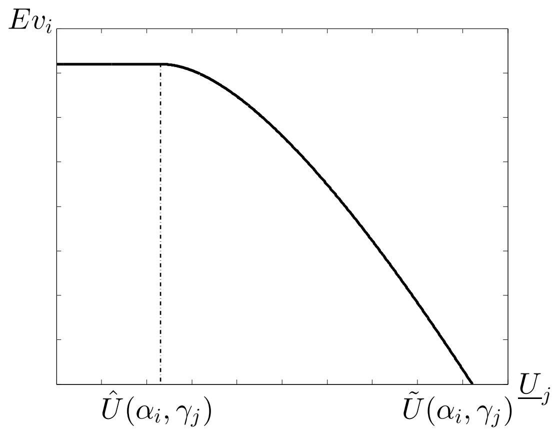


Figure 1.2: Company's profit under different $\underline{U}_j$.

However, in this market, for any $\underline{U}_j$ the academic's effort under moral hazard is always lower than the first-best effort $(e_j(W_{ij}(\underline{U}_j); p_i) < e_j^{FB})$.[17] The reason is that the good signal g may not be perfectly informative (i.e., $\pi(G|g) \leq 1$), so the company may still experience a failure in the future. This possible loss B reduces the expected revenue for the pharma company. Thus, companies reduce the incentive wage to academics, which always yields an effort lower than the first best one.

In this setup, low ability companies and low productivity academics may not be able to form a profitable collaboration with a participant on the other side of the market. This is because these firms of low-ability have high chances to suffer the failure. Consider a pair (p_i, a_j), imagine that academic a_j has the highest pro-

[17]Here, the first-best effort under symmetric information is $e_j^{FB} = [G\alpha_i - B(1-\beta)]\gamma_j$.

ductivity $\bar{\gamma}_j$. When p_i's ability is very low, there is no incentive contract between this company and the best academic $\bar{\gamma}_j$ that simultaneously gives the academic any reservation utility $\underline{U}_j \leq \tilde{U}(\alpha_i, \bar{\gamma}_j)$ and a positive profit for the company. Therefore, p_i will not find profitable to collaborate with any academic, and it is unmatched in this market. I denote the threshold of the company's ability by $\hat{\alpha}_i$; below $\hat{\alpha}_i$ the company is always unmatched. Similarly, there exists a threshold of the academic's productivity $\hat{\gamma}_j$ so that academics with $\gamma_j \leq \hat{\gamma}_j$ are unmatched. To have a market with at least one collaboration in equilibrium, the populations of academics and pharma companies need to satisfy some constraints. I summarize this result formally in Lemma 1.1.

Lemma 1.1. *Consider the sensitivity scenario. For a population of academics in* $[\underline{\gamma}_j, \bar{\gamma}_j]$*, there is a threshold* $\hat{\alpha}_i$ *such that when* $\alpha_i \geq \hat{\alpha}_i$*, company* p_i *with* α_i *will profit if it collaborates with academic* $\bar{\gamma}_j$*. If the population of pharma companies is* $[\underline{\alpha}_i, \bar{\alpha}_i]$*, and* $\hat{\alpha}_i > \underline{\alpha}_i$ *then any company with ability* $\alpha_i < \hat{\alpha}_i$ *is unmatched. A similar threshold* $\hat{\gamma}_j$ *for the academic's productivity exists.*

To discuss relevant markets, I assume that all companies' ability α_i and all academics' productivity γ_j are higher than $\hat{\alpha}_i$ and $\hat{\gamma}_j$, respectively.

The equilibrium matching

I analyze now the equilibrium matching in a stable market allocation when firms have the sensitivity evaluation technology. It is stated in Proposition 1.2.

Proposition 1.2. *Consider the sensitivity scenario. In a stable market allocation* $(\mu, \mathcal{W})$*, the equilibrium matching* μ *is positive assortative; that is, for any matched companies* p_i *and* $p_{i'}$*, with* $\alpha_i \geq \alpha_{i'}$*, then* $\mu(\alpha_i) \geq \mu(\alpha_{i'})$*.*

The equilibrium matching is PAM because a better company has a higher *MRS*. That is, a high-ability company benefits more from hiring a better academic than a low-ability company does. Let me give the intuition for why *MRS* increases in the company's ability by using the two-by-two example illustrated in Figure 1.3. In this figure I consider the possible partnerships between two pharma companies with $\alpha_i > \alpha_{i'}$ and two academics with $\gamma_j > \gamma_{j'}$. This figure shows the joint probability of a good signal and a success, $\pi(g,G)$. Obviously, this is the probability that firms care about. On the one hand, under a certain level of reservation utility $\underline{U}_j$, a company with higher α_i can motivate the academic to exert more effort because incentives are cheaper, which implies a higher prior $\pi(G)$. On the other hand, a higher $\pi(g|G) = \alpha_i$ induces a greater probability of receiving a good signal as a share of $\pi(G)$, i.e., $\pi(g,G) = \pi(g|G)\pi(G)$. Both effects are greater for a better company α_i, as shown by Figure 1.3, $(\pi_4(g,G) - \pi_3(g,G)) > (\pi_2(g,G) - \pi_1(g,G))$. That is, for a better company the raise in this likelihood is higher, thus, it profits more from it. Consequently, the higher-ability company can outbid the lower-ability company in the competition for the better academic.

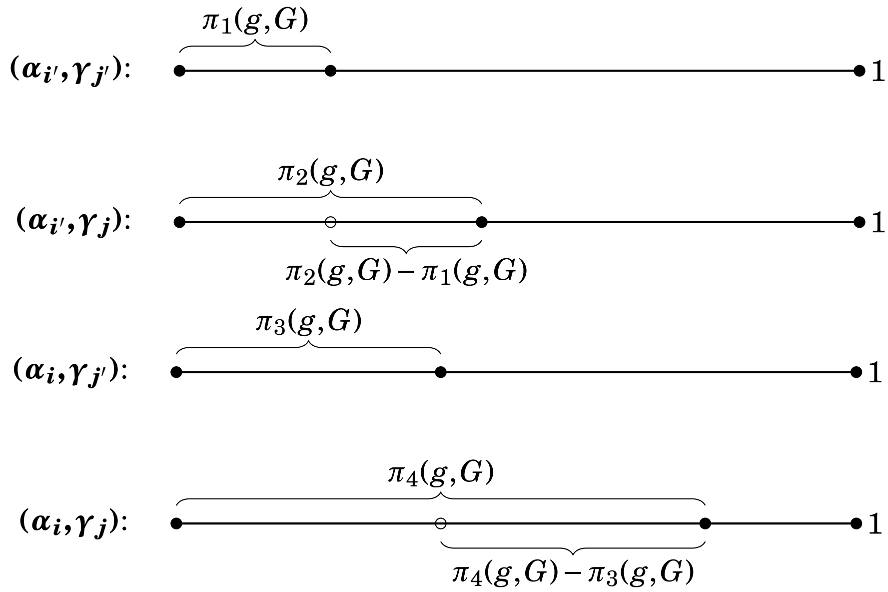


Figure 1.3: Intuition of PAM under the sensitivity setup where $\alpha_i > \alpha_{i'}$ and $\gamma_j > \gamma_{j'}$.

Finally, to illustrate how the better company outbids the worse company in the competition for the most productive academic, I provide a two-by-two numerical example, where the possible outcomes of a project are ($G = 0.75$, $B = -1$) and the companies' and academics' ability are $\alpha_1 = 1$, $\alpha_2 = 0.87$, $\beta = 1$, $\gamma_1 = 1$, and $\gamma_2 = 0.9$. In this two-by-two market, the low productivity academic will get the lowest expected utility from companies, that are $\hat{U}(\alpha_1,\gamma_2) = 0.05$ and $\hat{U}(\alpha_2,\gamma_2) = 0.04$ when she partners with company p_1 and p_2, respectively. Table 1.1 summarizes the efforts, wages, utilities, and profits for all possible partnerships in this market. In the competition for the high productivity academic a_1, companies p_1 and p_2 are ready to give her an extra utility ΔU_1 and ΔU_2 in addition to her lowest expected utility, that is, $\hat{U}(a_1,\gamma_1)+\Delta U_1 = 0.07+\Delta U_1$ and $\hat{U}(a_2,\gamma_1)+\Delta U_2 = 0.05+\Delta U_2$, respectively. Giving the academic these utility levels, implies for the companies to reduce their profits by Δv_1 and Δv_2. A company will quit the competition for a_1 when hiring (the low productivity) academic a_2 is weakly more profitable, for instance, p_2 quits the competition if $0.11-\Delta v_2 \leq 0.09$.

	e	w^g	Eu	Ev
(p_1,a_1)	$0.38+\Delta e_1$	$0.38+\Delta w_1$	$0.07+\Delta U_1$	$0.14-\Delta v_1$
(p_2,a_2)	0.29	0.38	0.04	0.09
(p_1,a_2)	0.34	0.38	0.05	0.11
(p_2,a_1)	$0.33+\Delta e_2$	$0.38+\Delta w_2$	$0.05+\Delta U_2$	$0.11-\Delta v_2$

Table 1.1: Effort, wage and utilities under competition.

	e	w^g	Eu	Ev
(p_1,a_1)	0.47	0.47	$0.07+0.04=0.11$	$0.14-0.01=0.13$
(p_2,a_2)	0.29	0.38	0.04	0.09
(p_1,a_2)	0.34	0.38	0.05	0.11
(p_2,a_1)	0.47	0.54	$0.05+0.06=0.11$	$0.11-0.02=0.09$

Table 1.2: Effort, wage and utilities in equilibrium.

In the stable allocation, as shown by Table 1.2, the worse company p_2 is indifferent between hiring a_1 and hiring a_2 since it obtains the same expected profit $Ev(p_2,a_1) = Ev(p_2,a_2) = 0.09$. To hire a_1, company p_1 offers a contract under which a_1 gets at least $Eu(a_1,p_1) = 0.11$ and the company obtains the profit $Ev(p_1,a_1) = 0.13$, higher than the one obtained when hiring a_2, i.e., $0.13 > Ev(p_1,a_2) = 0.11$. Thus, p_1 outbids in the competition for a_1, while the worse company p_2 hires a_2. As a consequence, the equilibrium matching is PAM.[18]

The numerical example is an extreme case, where two firms are heterogeneous in making type I error (α_i), and they will never make type II errors ($\beta = 1$). This

[18]In this numerical example, I have computed the profit and utility levels in the equilibrium that is best for the pharma companies. There are other equilibria. In all of them, the equilibrium matching is PAM, and the characteristics of the contracts are qualitatively the same. To explain the market competition, I introduce this numerical example, and I will not provide the numerical example for other scenarios because the process is the same.

example is an intuitive case for the project of exploitation. Exploitation is based on previous patents or research, and the firm perfectly knows the side effects of the compound or treatment. Therefore, when the drug or future treatment is a failure, the evaluation can always generate a bad signal. That is, firms never make type II errors when the collaborative project is of exploitation. However, firms may not know the effectiveness of the drug. Thus, depending on the firm's ability or experience, a better firm is less likely to make type I errors.

1.3.2 Specificity scenario: $\pi(g|G) = \alpha$, $\pi(b|B) = \beta_i$

Consider a different scenario, where pharma companies are heterogeneous in marking type II errors and homogeneous in making type I errors. The company's evaluation has the following form:

$$\pi(g|G) = \alpha, \quad \pi(b|G) = 1 - \alpha;$$
$$\pi(b|B) = \beta_i, \quad \pi(g|B) = 1 - \beta_i.$$

This evaluation technology could explain the project of exploration. For a collaborative project of exploration, there are no previous findings or studies. Thus, firms may not know much about the side effects of the drug or treatment. Therefore, firms are heterogeneous in making type II errors, and a better company with more experience has a lower probability of making mistakes.

For the market to be well defined, Assumption 1.2 guarantees the interior solution in equilibrium, that is, $\pi(G) \in [0,1]$ under moral hazard.

Assumption 1.2. $[G\alpha - B(1-\underline{\beta}_i)]\bar{\gamma}_j^2 \leq 1$.

The equilibrium contract

As in the previous market setup, because of limited liability, the equilibrium contract is a function of the endogenous reservation utility $\underline{U}_j$. As in the previous scenario, there are three regions of $\underline{U}_j$ in this market, separated by two thresholds: $\hat{U}(\beta_i,\gamma_j)$ and $\tilde{U}(\beta_i,\gamma_j)$. Using notation $X_{ij} = [G\alpha - B(1-\beta_i)](\alpha+\beta_i-1)\gamma_j^2$ to reduce expressions' length, the thresholds are:

$$\hat{U}(\beta_i,\gamma_j) = \frac{(X_{ij}+3(1-\beta_i))(X_{ij}-(1-\beta_i))}{8(\alpha+\beta_i-1)^2\gamma_j^2},$$

$$\tilde{U}(\beta_i,\gamma_j) = \frac{[X_{ij}+(1-\beta_i)+\sqrt{(X_{ij}-(1-\beta_i))^2+4(1-\beta_i)\beta_i^2\gamma_j^2 B}]^2-4(1-\beta_i)^2}{8(\alpha+\beta_i-1)^2\gamma_j^2}.$$

The equilibrium contract in this scenario is presented in Proposition 1.3. Let me use notation $Y_{ij} = \sqrt{(1-\beta_i)^2+2(\alpha+\beta_i-1)^2\gamma_j^2 Eu_j}$ to simplify expressions. Note that comparing to the similar expressions in the previous scenario, the heterogeneity in this case is β_i.

Proposition 1.3. *Consider the specificity scenario. In a stable market allocation* $(\mu,\mathscr{W})$*, for any matched pair* (p_i,a_j) *and any equilibrium reservation utility* $\underline{U}_j \leq \tilde{U}(\beta_i,\gamma_j)$*, the equilibrium contract* $W_{ij}(\underline{U}_j)$ *satisfies:*

a) the academic's expected utility is $Eu_j = \max\{\hat{U}(\beta_i,\gamma_j),\underline{U}_j\}$*;*

b) the payment scheme is $W_{ij}(\underline{U}_j) = (w_{ij}^g = \frac{Y_{ij}-(1-\beta_i)}{(\alpha+\beta_i-1)^2\gamma_j^2}, w_{ij}^b = 0)$*;*

c) the academic's optimal effort is $e_j(W_{ij}(\underline{U}_j);p_i) = \frac{Y_{ij}-(1-\beta_i)}{(\alpha+\beta_i-1)\gamma_j}$*;*

d) the company discontinues the project when a bad signal b reveals;

e) the company's expected profit is $Ev_i(W_{ij}(\underline{U}_j);a_j) = \frac{(X_{ij}-Y_{ij})(Y_{ij}-(1-\beta_i))}{(\alpha+\beta_i-1)^2\gamma_j^2}$.

The company's profit curve is similar to that in Figure 1.2. Moreover, the equilibrium effort under moral hazard is always lower than that in the first best. In addition, since the signal g is not fully informative, i.e., $\pi(G|g) \leq 1$, some low-ability firms and low-productive academics may not be matched in the market. I summarize this result formally in Lemma 1.2.

Lemma 1.2. *Consider the specificity scenario. For a population of academics in* $[\underline{\gamma}_j,\bar{\gamma}_j]$*, there is a* $\hat{\beta}_i$ *such that when* $\beta_i \geq \hat{\beta}_i$*, company* p_i *with* β_i *will profit if it* *collaborates with academic $\bar{\gamma}_j$. If the population of pharma companies is $[\underline{\beta}_i, \bar{\beta}_i]$, and $\hat{\beta}_i > \underline{\beta}_i$ then any company with ability $\beta_i < \hat{\beta}_i$ is unmatched. A similar threshold $\hat{\gamma}_j$ for the academic's productivity exists.*

To discuss relevant markets, I assume that all companies' ability β_i and all academics' productivity γ_j are higher than $\hat{\beta}_i$ and $\hat{\gamma}_j$, respectively.

The equilibrium matching

I present now the equilibrium matching in the scenario of specificity. The result is stated in Proposition 1.4.

Proposition 1.4. *Consider the specificity scenario. In a stable market allocation $(\mu, \mathscr{W})$, the equilibrium matching μ is negative assortative; that is, for any matched p_i and $p_{i'}$, with $\beta_i > \beta_{i'}$, then $\mu(\beta_i) < \mu(\beta_{i'})$.*

In this market, the equilibrium matching is NAM because worse pharma companies have steeper *MRS*. That is, they benefit more from hiring a better academic than a better company does. Let me explain the intuition for why *MRS* decreases in the company's ability by a two-by-two example illustrated in Figure 1.2 (where $\beta_i > \beta_{i'}$ and $\gamma_j > \gamma_{j'}$). In this figure, for short I denote $\pi = \pi(B)\pi(g|B)$ for all possible partnerships. Companies are concerned about the probability of having a failure in the future even when they observe the signal g. This probability is $\pi(B)\pi(g|B)$. Under the assumption $|B| \geq G$, one company's incentive for hiring a better academic mainly depends on the decrease in $\pi(B)\pi(g|B)$ it obtains. Hiring a better academic can decrease the prior probability of failure $\pi(B)$. In addition, when hiring a better academic, a company with $\beta_{i'}$ decreases $\pi(B)\pi(g|B)$ more than the one with β_i does since $\pi(g|B) = (1-\beta_i) < (1-\beta_{i'})$. As a consequence, the values $\pi_1, \pi_2, \pi_3, \pi_4$ in Figure 1.2 satisfy $|\pi_2 - \pi_1| > |\pi_4 - \pi_3|$.

To reduce the chances of suffering the loss B, the worse company $\beta_{i'}$ profits more from hiring a better academic than the better company β_i. Hence, the worse company outbids the better one in the competition for the better academic. Therefore, the equilibrium matching is NAM.

One may also consider that the probability of obtaining a good outcome when observing signal g, $\pi(G)\pi(g|G)$, will influence the equilibrium matching. Companies may want to increase $\pi(G)\pi(g|G)$ by hiring a better academic. But it is less relevant for the pharma companies than decreasing $\pi(B)\pi(g|B)$ because $|B| \geq G$. Thus, the determinant aspect is the decrease in $\pi(B)\pi(g|B)$ that I have discussed.

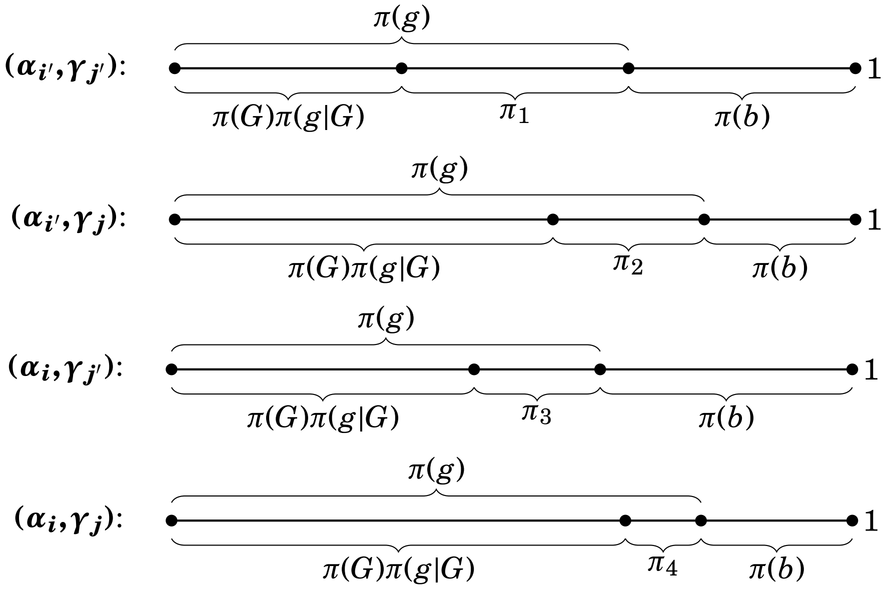


Figure 1.4: Intuition of NAM under the specificity setup where $\beta_i > \beta_{i'}$ and $\gamma_j > \gamma_{j'}$.

1.3.3 Symmetry scenario: $\pi(g|G) = \pi(b|B) = \alpha_i$

As a complementary case, I investigate the symmetry scenario, in which pharma companies' evaluation technology has the following form:

$$\pi(g|G) = \alpha_i, \quad \pi(b|G) = 1 - \alpha_i;$$
$$\pi(b|B) = \alpha_i, \quad \pi(g|B) = 1 - \alpha_i.$$

Similar to the previous scenarios, the following assumption ensures that probability $\pi(G) \in [0,1]$.

Assumption 1.3. $[G\underline{\alpha}_i - B(1-\underline{\alpha}_i)]\bar{\gamma}_j^2 \leq 1$.

The equilibrium contract

Remember that the pharma company only decides whether to continue the project when receiving a bad signal. To introduce the thresholds for $\underline{U}_j$, again let me assume that the company always abandons the project when receiving signal b (this will be proven in equilibrium). To simplify the expressions I use $\hat{X}_{ij} = [G\alpha_i - B(1-\alpha_i)](2\alpha_i - 1)\gamma_j{}^2$. The thresholds are:

$$\hat{U}(\alpha_i, \gamma_j) = \frac{(\hat{X}_{ij} + 3(1-\alpha_i))(\hat{X}_{ij} - (1-\alpha_i))}{8(2\alpha_i - 1)^2 \gamma_j{}^2},$$

$$\tilde{U}(\alpha_i, \gamma_j) = \frac{[\hat{X}_{ij} + (1-\alpha_i) + \sqrt{(\hat{X}_{ij} - (1-\alpha_i))^2 + 4(2\alpha_i - 1)^2 \gamma_j{}^2 (1-\alpha_i) B}]^2 - 4(1-\alpha_i)^2}{8(2\alpha_i - 1)^2 \gamma_j{}^2}.$$

The equilibrium contract of this market is presented in Proposition 1.5. Using notation $\hat{Y}_{ij} = \sqrt{(1-\alpha_i)^2 + 2(2\alpha_i - 1)^2 \gamma_j{}^2 E u_j}$:

Proposition 1.5. *Consider the symmetry scenario. In a stable market allocation, for any matched pair (p_i, a_j), if $\underline{U}_j \le \tilde{U}(\alpha_i, \gamma_j)$, the equilibrium contract $W_{ij} = (w^g_{ij}, w^b_{ij})$ satisfies:*

a) the academic's expected utility is $Eu_j = \max\{\hat{U}(\alpha_i, \gamma_j), \underline{U}_j\}$;

b) the payment scheme is $W_{ij}(\underline{U}_j) = (w^g_{ij} = \frac{\hat{Y}_{ij} - (1-\alpha_i)}{(2\alpha_i - 1)^2 \gamma_j{}^2},\ w^b_{ij} = 0)$;

c) the academic's effort is $e_j(W_{ij}(\underline{U}_j); p_i) = \frac{\hat{Y}_{ij} - (1-\alpha_i)}{(2\alpha_i - 1)\gamma_j}$;

d) the pharma company discontinues the project when a bad signal b reveals;

e) the pharma's expected profit is $Ev_i(W_{ij}(\underline{U}_j); a_j) = \frac{(\hat{X}_{ij} - \hat{Y}_{ij})(\hat{Y}_{ij} - (1-\alpha_i))}{(2\alpha_i - 1)^2 \gamma_j{}^2} + B(1-\alpha_i)$.

As in the previous two markets, for any $\underline{U}_j \le \hat{U}(\alpha_i, \gamma_j)$, the equilibrium contract is the same for a pair of (p_i, a_j). This contract yields the highest profit for the company. When $\underline{U}_j > \hat{U}(\alpha_i, \gamma_j)$, the contract ensures the academic exactly $\underline{U}_j$, and leads to a lower company's profit. The company's profit curve is similar to that in Figure 1.2. I first discuss which companies and academics will never form a collaboration in equilibrium, and then I present the characteristics of the thresholds

$\hat{U}(\alpha_i,\gamma_j)$ and $\tilde{U}(\alpha_i,\gamma_j)$.

As in the specificity market, the low-ability company and the low-productivity academic may not be able to form a profitable collaboration with any participant on the other side of the market. The following lemma presents this result.

Lemma 1.3. *Consider the symmetry scenario. For a distribution of the academics defined in* $[\underline{\gamma}_j,\bar{\gamma}_j]$*, there exists* $\hat{\alpha}_i$ *such that when* $\alpha_i \geq \hat{\alpha}_i$*, pharma company* p_i *will profit from collaborating with best academic* $\bar{\gamma}_j$*. If the distribution of companies is* $[\underline{\alpha}_i,\bar{\alpha}_i]$*, and* $\hat{\alpha}_i > \underline{\alpha}_i$ *then any company with* $\alpha_i < \hat{\alpha}_i$ *is unmatched. Similarly, a threshold* $\hat{\gamma}_j$ *for the academic's productivity also exists.*

Let me assume that all companies' ability α_i and all academics' productivity γ_j are higher than $\hat{\alpha}_i$ and $\hat{\gamma}_j$, respectively.

The equilibrium matching

I state the equilibrium matching for the symmetry scenario in Proposition 1.6.

Proposition 1.6. *Consider the symmetry scenario. In the stable market allocation* $(\mu,\mathscr{W})$*, the equilibrium matching* μ *is negative assortative; that is, for any matched pharma companies* p_i*,* $p_{i'}$ *with* $\alpha_i > \alpha_{i'}$*, then* $\mu(\alpha_i) < \mu(\alpha_{i'})$*.*

The intuition of NAM in this market is similar to that provided in the specificity scenario.

1.3.4 Relationship between an academic's productivity γ_j and her payment in the case of receiving a good signal w_{ij}^g

Under moral hazard, it is interesting to understand the relationship between the academic's productivity and her bonus when receiving a good signal, among other things because these data may be available for research. The previous literature on two-sided matching markets with moral hazard has shown that the conclusions on this issue may crucially differ from the one obtained when considering an isolated, one company and one academic partnership. In this section, I study the equilibrium relationship between the academic's productivity γ_j and her payoff in case of receiving a good signal w^g_{ij}.[19]

Considering an isolated partnership, there would be no competition and the academic would obtain exactly $\hat{U}(t_i, \gamma_j)$. One can check that in all cases, an academic's remuneration is increasing in her productivity, i.e., $\frac{\partial w^g_{ij}}{\partial \gamma_j} > 0$. However, the relationship between γ_j and w^g_{ij} is affected by the competition and the equilibrium matching in the two-sided matching market. To simplify the discussion, let me assume that the population of pharma companies and academics are uniformly distributed. Moreover, assume that all companies and academics can be matched, and the two sides have the same amount of participants.[20]

An increase in the academic's productivity γ_j influences the payoff w^g_{ij} through the combination of three effects: (i) there is a direct effect on the payoff from this increase; (ii) there is a matching indirect effect, because the academic with a higher productivity may be matched with a better or a worse company, depending on the equilibrium matching in the market; (iii) there is an indirect effect associated to the variation of the equilibrium endogenous reservation utility $\underline{U}_j$. That is, in equilibrium, $\underline{U}_j$ may be higher because of the competition for a better academic. The combination of these three effects may imply different relationships between γ_j and w^g_{ij}. I will discuss this relationship in the sensitivity and the specificity scenarios, and will not discuss the symmetry setup because it is similar to the second one.

In a sensitivity setup, the equilibrium matching is PAM. Since one company is matched with one academic and vice versa, the mass of the matched companies must be equal to that of the matched academics (*measure consistency*). Measure consistency yields the following equilibrium relationship between the company's

[19]The payment schemes in all setups have the form $(w^g_{ij}, 0)$. Thus, to describe the payment scheme I only need to discuss the bonus if a good signal is obtained.

[20]Remember that some participants may not be matched in the market. Without this assumption, the result still holds but it requires more complicated discussions.

and the academic's ability (i.e., the matching function):

$$\int_{\underline{\alpha}_i}^{\alpha_i} \frac{1}{\bar{\alpha}_i - \underline{\alpha}_i} dx = \int_{\underline{\gamma}_j}^{\gamma_j} \frac{1}{\bar{\gamma}_j - \underline{\gamma}_j} dy \Rightarrow \alpha_i(\gamma_j) = \frac{\bar{\alpha}_i - \underline{\alpha}_i}{\bar{\gamma}_j - \underline{\gamma}_j}\gamma_j + \frac{\underline{\alpha}_i\bar{\gamma}_j - \bar{\alpha}_i\underline{\gamma}_j}{\bar{\gamma}_j - \underline{\gamma}_j}.$$

Clearly, this matching function increases in γ_j due to PAM. The equilibrium reservation utility $\underline{U}_j$ is often greater than $\hat{U}(\alpha_i, \gamma_j)$. Then, differentiating w^g_{ij} with respect to γ_j, I obtain:

$$\frac{dw^g_{ij}}{d\gamma_j} = \underbrace{\frac{\partial w^g_{ij}}{\partial \gamma_j}}_{\text{direct effect}<0} + \underbrace{\frac{\partial w^g_{ij}}{\partial \alpha_i}\frac{\partial \alpha_i(\gamma_j)}{\partial \gamma_j}}_{\text{matching effect}<0} + \underbrace{\frac{\partial w^g_{ij}}{\partial \underline{U}_j}\frac{\partial \underline{U}_j}{\partial \gamma_j}}_{\text{competition effect}>0}.$$

In this scenario, the direct effect is negative because a more productive academic needs fewer incentive to provide the effort. The matching effect is negative since she is matched with a better company whose evaluation technology is better ($\frac{\alpha_i(\gamma_j)}{\partial \gamma_j} > 0$). On the other hand, using the evaluation technology in this case, the high-ability company can better motivate this academic to exert the effort and pay her less, i.e., $\frac{\partial w^g_{ij}}{\partial \beta_i} < 0$. As for the last term, the competition effect is also positive since $\frac{\partial w^g_{ij}}{\partial \underline{U}_j} > 0$ and $\frac{\partial \underline{U}_j}{\partial \gamma_j} = -\frac{\partial E v_i / \partial \gamma_j}{\partial E v_i / \partial \underline{U}_j} > 0$. That is, to partner with a more productive academic with higher reservation utility, the company has to pay her more to ensure that level of utility. Therefore, in the sensitivity market, the relationship between the academic's productivity and the payoff can be always positive, always negative or neither of them depending on the combination of these three effects.

In the specificity scenario, the equilibrium matching is NAM, and the measure consistency yields the following matching function:

$$\int_{\underline{\beta}_i}^{\beta_i} \frac{1}{\bar{\beta}_i - \underline{\beta}_i} dx = \int_{\gamma_j}^{\bar{\gamma}_j} \frac{1}{\bar{\gamma}_j - \underline{\gamma}_j} dy \Rightarrow \beta_i(\gamma_j) = -\frac{\bar{\beta}_i - \underline{\beta}_i}{\bar{\gamma}_j - \underline{\gamma}_j}\gamma_j + \frac{\bar{\beta}_i\bar{\gamma}_j - \underline{\beta}_i\underline{\gamma}_j}{\bar{\gamma}_j - \underline{\gamma}_j}.$$

This matching function decreases in γ_j because of NAM. The first order derivative of payoff w^g_{ij} with respect to γ_j is:

$$\frac{dw^g_{ij}}{d\gamma_j} = \underbrace{\frac{\partial w^g_{ij}}{\partial \gamma_j}}_{\text{direct effect}<0} + \underbrace{\frac{\partial w^g_{ij}}{\partial \beta_i}\frac{\partial \beta_i(\gamma_j)}{\partial \gamma_j}}_{\text{matching effect}<0} + \underbrace{\frac{\partial w^g_{ij}}{\partial \underline{U}_j}\frac{\partial \underline{U}_j}{\partial \gamma_j}}_{\text{competition effect}>0}.$$

The first term of the derivative is negative because a lower productivity academic requires more incentives to provide the same effort. Thus, a company chooses to increase w^g_{ij} when γ_j is lower. The indirect matching effect is negative since $\frac{\partial w^g_{ij}}{\partial \beta_i} > 0$ and $\frac{\partial \beta_i(\gamma_j)}{\partial \gamma_j} < 0$, given that the matching is NAM. However, the reason is different from that in the previous scenario. A better company would like to pay a more productive academic more but the matching is NAM. A better academic is matched with a worse firm that pays her less. Finally, the competition effect is positive because $\frac{\partial w^g_{ij}}{\partial \underline{U}_j} > 0$ and $\frac{\partial \underline{U}_j}{\partial \gamma_j} = -\frac{\partial E v_i / \partial \gamma_j}{\partial E v_i / \partial \underline{U}_j} > 0$. Therefore, the relationship between γ_j and w^g_{ij} may be always positive, always negative, or neither of them depending on the population of companies and academics. The following proposition states the combined effect of these three aspects.

Proposition 1.7. *In all scenarios, w^g_{ij} may be always increasing or always decreasing or non-monotonic in γ_j. Therefore, the shape of w^g_{ij} as a function of γ_j may differ from the relationship between w^g_{ij} and γ_j obtained in an isolated partnership.*

This proposition shows that better academics may obtain a lower bonus than less able academics in the market. This result does not contradict the fact that a better academic gets a higher utility.[21] Because the academic's utility is determined by the combination of the (lower) payoff, the cost of (lower) effort, and the probability of obtaining the bonus. In the end, the combination of these effects will increase the more productive academic's utility.

[21]As I have shown that a more productive academic's endogenous reservation utility is always higher because all companies want to hire a better academic.

1.3.5 Summary of the three scenarios

Before discussing some extensions, let me briefly summarize the results obtained so far. First, in each scenario, the pharma company discontinues the project when receiving a bad signal. Second, the characteristics of equilibrium matching is determined by the structure of the company's evaluation. Table 1.3 summarizes the equilibrium matching in different markets.

Scenario	Sensitivity	Specificity	Symmetry
Evaluation structure	$\pi(g\|G) = \alpha_i$ $\pi(b\|B) = \beta$	$\pi(g\|G) = \alpha$ $\pi(b\|B) = \beta_i$	$\pi(g\|G) = \alpha_i$ $\pi(b\|B) = \beta_i = \alpha_i$
Matching	PAM	NAM	NAM

Table 1.3: Equilibrium matching in different markets.

1.4 Extensions and discussions

In this section, I extend and discuss some interesting results under different assumptions from the initial ones.

1.4.1 Correlation between the size of the good outcome G and the company's ability t_i

Up to now, the successful outcome G is exogenous and the same for all the pharma companies in the market. However, one may consider that the size of this outcome mat be related to the pharma company's ability. That will be the case, for example, when a company with more experience in developing the medical products (has better evaluation technology) may also be better at discovering the higher outcome project. In this subsection, I consider the existence of a positive correlation between t_i and G. This correlation will not affect the characteristic of the equilibrium matching in the sensitivity market (which is PAM). The intuition is that a positive correlation among this variables further increases profit for the better company. It will have stronger motivations to outbid the worse company in the competition for the better academic. I concentrate here on the implication of this positive correlation for the specificity scenario, where the equilibrium matching was NAM.[22] Assume that the size of the successful outcome is a concave function of the pharma company's evaluation technology. Denote this function by $G(\beta_i)$, with $G'(\beta_i) \geq 0$ and $G''(\beta_i) \leq 0$. The characteristic of the equilibrium matching in this market depends on the sign of the following expression:

$$\underbrace{[G'(\beta_i)+B]}_{\gtrless 0?}\underbrace{(\alpha+\beta_i-1)^2\gamma_j{}^2Y_{ij}^2}_{>0}+\underbrace{(Y_{ij}-2(1-\beta_i))(Y_{ij}-X_{ij}-(1-\beta_i))}_{<0}>0\ (<0) \rightarrow \text{PAM (NAM)}.$$

The property of the first derivative $G'(\beta_i)$ influences the first term of the previous expression. Depending on the sign and the size of the first term, the equilibrium matching may be PAM or NAM or neither of them. Since $G''(\beta_i) \leq 0.$, if the expression $[G'(\beta_i)+B]$ is negative for the lowest $\underline{\beta}_i$ in the population, the equilibrium matching is always NAM. If $[G'(\beta_i)+B]$ is positive for the highest $\bar{\beta}_i$ in the market, and it is high enough, so that whole expression is positive then the equilibrium matching is PAM. But there are other cases where for the low evaluation technology companies the partnerships are PAM, and for the companies in the other extreme of the distribution the matching is NAM because $G''(\beta_i) < 0$. The intuition is that when these two characteristics are positively correlated, better companies are more willing to pay more to attract the better academics. If this new effect is high enough it may lead companies with high β_i to outbid companies with low β_i in the competition for the better academics. However, the matching depends on the marginal increase of G, i.e., $G'(\beta_i)$. For instance, if this marginal increase is still too low for the worst firm in the market, the matching is still NAM. On the other hand, if it is high enough even for the best firm, this positive correlation between G and β_i will switch NAM to PAM. In other cases, the matching may be neither PAM nor NAM.

[22]The effect of this positive correlation on the equilibrium matching in the symmetry scenario is similar to that in the specificity market.

1.4.2 Pharma companies differ in the structure of their evaluation technology

In the initial model, to make the use of the SC condition, I assumed that in a market all the companies have the same evaluation structure. Now I will study a case where the pharma companies have different evaluation structures. To simplify the discussion, I consider only two pharma companies and only two academics: pharma company, "α", has a perfect sensitivity evaluation structure with $\alpha \in [\underline{\alpha}, \bar{\alpha}]$ and $\beta = 1$, while the other company, "β", has a perfect specificity evaluation structure, with $\alpha = 1$ and $\beta \in [\underline{\beta}, \bar{\beta}]$. The two academics, academic a_1 and a_2 are such that $\gamma_1 > \gamma_2$.

In this example, it is not possible to define about PAM or NAM since the two firms have different evaluation technology, and they cannot be ranked in terms of their quality. As expected, I show that given γ_1 and γ_2, the characteristics of the equilibrium matching depends on the parameters α and β.

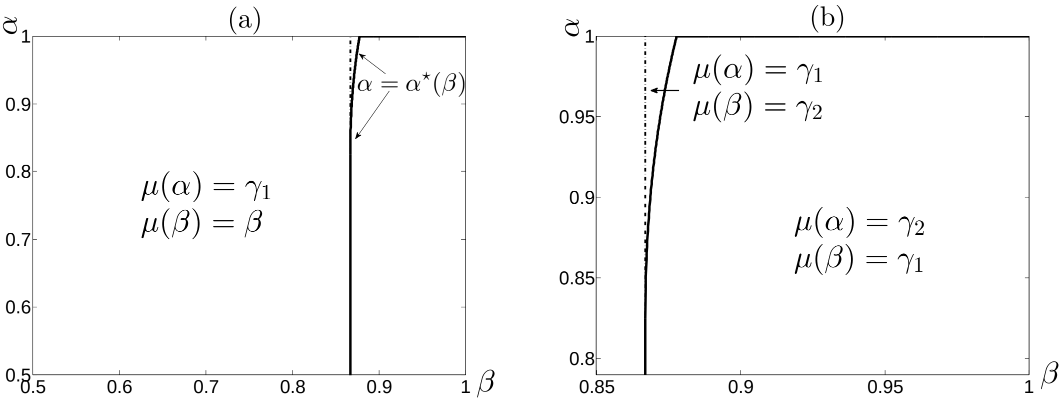


Figure 1.5: Illustration of the equilibrium matching in the space (β, α) when companies have different evaluation structures. On the left of the dashed line, β is unmatched. (b) shows the details of upper part of the figure (a).

Proposition 1.8. *Given a level of β, there is a threshold $\alpha^\star(\beta)$ such that:*

(i) When the partnership with a_2 is profitable for firm β, the matching equilibrium is: if $\alpha \leq \alpha^\star(\beta)$, then $\mu(\alpha) = \gamma_2$ and $\mu(\beta) = \gamma_1$; and if $\alpha > \alpha^\star(\beta)$, then $\mu(\alpha) = \gamma_1$ and $\mu(\beta) = \gamma_2$.

(ii) When the partnership with a_2 is not profitable for firm β, the matching equilibrium is: $\mu(\alpha) = \gamma_1$ and $\mu(\beta) = \beta$ (β is unmatched).

These equilibria are illustrated in Figure 1.5 in the space (β,α), taking $G = \frac{3}{4}$, $B = -1$, $\gamma_1 = 1$ and $\gamma_2 = 0.8$. The solid line represents $\alpha^\star(\beta)$. The intuition behind the result in Proposition 1.8 is that β may receive a bad outcome B even when the signal is g. To avoid this possible loss, its contract tends to ensure academic a_1 a higher expected utility than company α. Thus, if the parameter α is not high enough ($\alpha \le \alpha^\star(\beta)$), α will be matched with a_2 in equilibrium.

1.4.3 What if $G > |B|$?

In this section, I discuss how the results will change if the assumption $|B| > |G|$ no longer holds. To simplify the discussion, let me consider $G \gg |B|$. Let me point two facts. Under assumption $G \gg |B|$, first, in all scenarios now the expected outcome is larger than in Section 3, thus, pharma companies may decide to continue the project when signal is b. Second, the characteristics of the equilibrium matching may differ from the ones obtained in Section 3.

When $G \gg |B|$, for a pair (p_i,a_j), company p_i's continuation decision when receiving signal b may depend on the level of $\underline{U}_j$.[23] If $\underline{U}_j$ is low, the academic will supply low effort, which implies a low probability $\pi(G)\pi(b|G)$. Hence, company p_i anticipates the revenue after observing signal b, and abandoning the project is more profitable since the project is very likely to deliver a failure. In contrast, if $\underline{U}_j$ is high enough, it implies a large $\pi(G)\pi(b|G)$. Given $G \gg |B|$, the company may profit from continuing the project even after receiving signal b. If in equilibrium continuing the project is more profitable under b, the information from the evaluation technique is only used to monitor the academic. In addition, since firms may always choose to continue the project whatever the signal is, the equilibrium matching in each scenario may be different from that under the initial assumption $|B| \ge G$.

[23]See the last part of the proof of Proposition 1.1, whether the firm chooses to continue or abandon the project depends on a threshold of Y_{ij}, which is a function of $\underline{U}_j$.

1.5 Conclusion

This paper investigates the collaboration agreements between pharmaceutical companies and academics in a two-sided matching market, where each company hires one academic to develop its own drug developing project. At the interim stage, companies conduct an evaluation test on the academic's proof-of-concept results, and this evaluation allows companies to assess risks and to decide whether to abandon the project. Such evaluation can take the form of some data analysis using artificial intelligence on the compounds or a pre-clinical trial on animals for the drug.

Heterogeneous pharma companies compete for heterogeneous academics in this market. This implies a competitive equilibrium outcome, consisting of a menu of equilibrium contracts for each collaboration and an equilibrium matching between them. In this paper, I consider and study three particular scenarios characterized by the companies' evaluation technology. Assuming that the losses associated to a failure or the costs of pursuing a project with low value in case of success are very high, I find that in these three scenarios, companies always abandon the project when receiving a negative signal from the evaluation.[24]

The equilibrium contracts share similar characteristics in different scenarios. The analysis of the market equilibrium shows that the structure of the evaluation technology has important implications on the characteristics of the equilibrium matching. In the sensitivity market equilibrium, better pharma companies collaborate with better academics (positive assortative matching). In the other two scenarios, the matching is negative assortative matching, where the most accomplished academics collaborate with the lower evaluation ability companies because relatively they profit more from hiring those academics.

One can also consider other evaluation techniques rather than the particular evaluation that I proposed, of which results will be similar. For example, with a

[24] In the real world, sometimes companies do not react to bad news. There are important examples of company's managers in charge of the innovation process who chose to continue the projects even after receiving many negative reports about the project, and at the end companies suffer huge losses. See, for instance, Keil (1995a) and (1995b).

type of evaluation technique, companies care more about how much a more productive academic can increase the chance of obtaining a successful outcome instead of reducing the probability of a failure. A firm with better evaluation ability makes fewer errors in the evaluation. Therefore, when it cooperates with a more productive academic, it has a higher likelihood of having a good outcome in the future when a positive report is revealed from the evaluation. In consequence, the equilibrium matching will be PAM. In contrast, imagine that with the other evaluation technology, if firms care more about how much a better academic can reduce the chance of receiving a failure in the future, then the equilibrium matching is NAM. The reason is the other way around.

Moreover, contracts I obtain are different from the ones for an isolated partnership of a pharma company and an academic (the situation where there is no market or no competition because all participants are homogeneous). The reason is that the characteristics of the equilibrium matching and the competition in the market matter. In the matching market I considered, a better academic may not be paid a higher bonus, her remuneration in case of receiving a positive signal may be lower than the one received by a lower productive academic. However, the expected utility in the market is increasing in the productivity of the academics because of the stronger competition for a better academic.

In this paper, I concentrate on the collaborations between pharmaceutical companies and academics. Some other university-industry alliances (e.g., in software engineering and aerodynamics) share the same characteristics: they are characterized by risks and uncertainties, and the proof-of-concept obtained by the academic is far from the commercial version of a product, and its benefits would be only realized in the future. In addition, at an interim stage, companies run evaluation tests on the expected profitability of the collaborative project before engaging in further investment (Perkmann et al., 2011). Therefore, the conclusion of my model could also be suitable for the analysis of collaborations in these fields.

My approach can also be adapted to analyze other applications sharing the basic elements of my model. For example, with the appropriate changes, it can be useful to study the board of directors-CEOs matching, the CEO appointment, performance evaluation and remuneration. The CEO's behavior and her strategy decision determine the company's outcome in the future. The important uncertainties lead the board to evaluate the CEO's performance and to make predictions of the long-term effect of the CEO's strategy. This evaluation allows the board to remunerate the CEO and decide whether to continue with the CEO strategy or change it and may even dismiss the CEO. The other possible application is the matching between venture capitals and start-ups.

The approach of this paper is theoretical, while inspired by the existence of numerous university-industry collaborations. Some papers discuss the advantages and characteristics of the industry-university alliances, and a few of them conduct empirical analysis on the observed matching between firms and academics.[25] There are still few theoretical papers studying how and why companies and academics are involved in partnerships. My paper provides a theoretical approach to these questions and offers possible explanations for some results in empirical studies.

One important assumption in this paper is that participants are involved only once (one-period game). However, the partnership between pharma companies and academics institutions may be long-term relationship, and after abandoning a project, the academic may move to develop another project or explore another avenue. And this process may be repeated until a positive signal is obtained. Extending the static model to a dynamic case would be interesting for future studies.[26]

[25] An example is Mindruta (2013), which investigates the collaborations between biotech companies and academics using a matching approach. Her analysis shows which characteristics of the companies and the academics are complementary and substitutable in their collaborations. For instance, firm's size and scientist's patenting capabilities are also substitutable. This means that these two elements are negatively associated, which could be explained by my results. Banal-Estañol et al. (2018) also use a matching approach to study the industry-university partnerships on engineering research projects in the UK and find that in the observed collaborations firms' and academics' abilities are complementary, as their research orientations (applied or basic research) is. However, none of these papers provides a theoretical framework.

[26] For instance, extending the repeated dynamic moral hazard problem is studied by (Chade and Kovrijnykh, 2016).

Chapter 2

The Impact of Consumer's Regret on Firms' Decisions in a Durable Good Market

2.1 Introduction

"I see it all perfectly; there are two possible situations - one can either do this or that. My honest opinion and my friendly advice is this: do it or do not do it - you will regret both"
— Søren Aabye Kierkegaard.

Regret is a pervasive and powerful emotion well documented in the psychology literature.[1] Consumers frequently experience regret when they realize that they have made a mistake in their purchasing decisions because the forgone alternative would have been better. Sometimes, consumers are aware of the possibility of ex-post regret, which influences their consumption behavior.[2] Regret is even more common in markets for durable goods because the cost of replacing a product after

[1]See, for instance, Landman (1987), Landman (1993), and Gilovich and Medvec (1995).

[2]The effect of regret on the individual's behavior is studied and documented by economic papers, for instance, Loomes and Sugden (1982), Van de Ven and Zeelenberg (2011), and Giorgetta et al. (2013).

purchase may be prohibitively high. It is also more likely to occur in markets where the product design evolves rapidly, including mobile phones, digital cameras, and electric vehicles because consumers may find it difficult to learn the utilization of new attributes from an improved version. This uncertainty may result in potential ex-post regret. When consumers' expectation of regret impacts their purchasing decisions, firms factor this into their market tactics since it will influence the demand, price and overall profit.

In this paper, I study how consumers' anticipated regret affects their purchasing behavior and firms' price setting as well as profits in a durable good market. I propose a two-period sequential game where an incumbent sells its basic version of a good in both periods. An entrant introduces an improved version to the market. Although this entrant's version will not be available until the second period, the entrant displays the product's additional functions during the first period to induce some buyers to wait.[3]

In this market, each consumer decides whether to buy the incumbent's version in the first period or wait until the entrant's version is available in the second period and determine which version to buy. Since the entrant's version is not accessible in the first period, a consumer cannot test it, and she does not know whether she will appreciate the new functionalities. This uncertainty may result in two possible sources of regret, and I assume that the consumer can anticipate the potential regret. One sort of regret arises when she buys the incumbent's version in the beginning and afterward realizes that she prefers the entrant's version more. Then, she will regret having bought the incumbent's version. I refer to this regret as *action regret*. The other type of regret appears when she waits for the entrant's version, and discovers that she does not like new features and regrets waiting. I refer to this type of regret as *inaction regret*. The anticipation of one or the other type of regret may ex-ante affect consumers' purchasing behaviors since it influences consumers' ex-ante valuation of the goods (Zeelenberg et al., 1996; Zeelenberg, 1999).

[3]For instance, in 2016, the Chinese electric vehicle startup Nio claimed to produce a vehicle called ES8, but it was only launched until 2018.

This setup enables discussion of the impact of consumers' anticipated (action or inaction) regret on firms' pricing decisions and profits considering the product's durability. I also investigate whether a firm is interested in alerting consumers about the regret to strengthen their feelings and to increase its profit.

I begin by providing a benchmark case where consumers do not anticipate any regret. Then, I discuss two types of regret separately to show influences on consumers' behavior and firms' profits more clearly. Unsurprisingly, the anticipated action regret always benefits the entrant, while the inaction regret always harms it. Indeed, if a customer expects to regret not waiting to check out the entrant's version, she will be less inclined to buy the incumbent's version in the first place. As a result, demand for the entrant's good increases, providing an incentive for the entrant to raise its price, implying a higher profit. The reverse occurs if a consumer anticipates inaction regret. She will be more eager to buy the incumbent's product in the first period, which reduces the entrant's demand and price, and hence lowers its profit.

Anticipated regret may have different implications on the incumbent's profit. A stronger sense of action regret increases its prices but decreases the demand in the first period. Combined effects on prices and the demand reduce its profit in the first period (where a lower demand dominates a higher price) but increase the one in the second period (where both demand and price are higher). The inaction regret has opposite impacts.

From the analysis, each type of regret may increase, decrease, or induce a U-shape on the incumbent's profit as a function of the regret intensity. This mainly depends on the new attributes of the entrant's product, which also influence the demand and pricing strategy. For instance, when the level of new attributes is high enough, a stronger feeling of action regret implies that the profit increase in the second period dominates the decrease in the first period, which yields a higher overall profit for the incumbent. This is because new attributes of high quality have already induced a large amount of consumers to wait for the second period, thus, it gives the incumbent's profit in this period more weight. However, in other cases, the incumbent's total profit may decrease when new attributes are of low quality and have a U-shape when they are at the intermediate level. Consequently, the anticipated action regret may create a win-win scenario for both companies, and inaction regret has the opposite impact, which may result in a lose-lose situation for them.

In addition, this research explores whether a firm would seek to influence customers' regret sentiment by reminding or intensifying them through possible advertisements. Given my early discussion, the entrant frequently reminds consumers of action regret to persuade them to wait for its version. However, the incumbent may or may not attempt to find a way to remind consumers about potential regret, and its strategy is complicated.

Finally, as an extension, I investigate the case where consumers simultaneously anticipate both types of regret. I analyze which type of regret has a greater impact on a company's profit. Moreover, I address the idea that the incumbent may provide consumers with a free minor upgrade to mitigate the possible negative effect of regret. However, this improvement may have a detrimental effect on the incumbent's earnings in two scenarios. First, when the incumbent profits from a stronger action regret. Second, when a stronger feeling of inaction regret decreases its profit. This is because the free upgrade has the same impact as inaction regret, but it has the inverse effect of action regret.

This paper is related to regret theory, a behavioral deviation from the classical approach to preferences, documented by many theoretical and experimental works.[4] Based on experiments, many papers study the impact of anticipated regret on the individual's behavior. Simonson (1992) suggests that both purchase timing and brand choice can be influenced by regret. Shih and Schau (2011) find that a high perceived rate of innovation leads to increased anticipated regret regarding

[4]Loomes and Sugden (1982) provide the basis for regret theory as an alternative to the prospect theory by Kahneman and Tversky (1979), which allows explaining some choices under uncertainty that are inconsistent with the traditional utility theory. Loomes and Sugden (1982) and Bell (1982) suggest that some phenomena, which violate the conventional theory, can be explained by anticipated regret or anticipated rejoicing. Gilovich and Medvec (1995) review the evidence of action and inaction regret in psychology.

the purchase of the current best technology, which in turn leads to upgrade delays. Inman and Zeelenberg (2002) show that repeatedly buying an old product and purchasing a different product may lead to varying levels of regret, which depends on the prior experience of using the old good. Therefore, in this paper, to analyze the effect of each type of regret, I discuss a case where consumers anticipate two sorts of regret separately because these two regrets are independent.

Nasiry and Popescu (2012) discuss the influence of anticipated regret on the consumer's purchase decision and a monopolist's strategy. The monopolist may decide whether to advance sell its good when consumers are uninformed about the true valuation of the product.

The closest paper is Jiang et al. (2016). The authors investigate the impact of regret on an entrant's endogenous choice to develop an innovation of a product and firms' profits in a one-period duopoly setting, where the incumbent and entrant decide their prices simultaneously. They show that both types of regret can increase or decrease the entrant's investment in the innovation and benefit or harm the earnings of both firms at the same time. Thus, the impact of regret can go either way. The key distinction that leads to varied outcomes between our papers is the product's durability.

This paper is also related to the durable product literature that has considered the firm's pricing strategy. For example, Board (2008) solves for the durable-good monopolist strategy when consumers' population varies over time and illustrates how consumers' ability to delay consumption influences the shape of the optimal pricing. Hoppe and Lee (2003) find that the durability of the good either acts as an entrance barrier itself or creates an opportunity for the incumbent firm to deter entry by limiting pricing. In this paper, to analyze the effect of regret, I propose an assumption such that the entrant firm profits from entering the market.

To my knowledge, there is no paper studying the impact of consumer's anticipated regret in a durable good market. I believe this is a natural setup for analyzing action and inaction regret as part of plausible consumers' references.

The rest of the paper is organized as follows. Section 2 describes the model. In section 3, I discuss the results without any anticipated regret as a benchmark case. In section 4, I present results when consumers anticipate regret. In section 5, I discuss the extensions. Section 6 concludes.

2.2 Model

I consider a two-period model ($t \in \{1,2\}$) of a market for a durable good, where for simplicity, I assume that there is no discount factor.[5] Each consumer buys at most one unit of product, and the utility of not purchasing any good is zero. There is no reselling market, which means that she has to use it until the end of the second period once she buys a product.[6] In this section, I describe the basic model without regret to show the sequential game in this duopoly market, and later in section 4, I will introduce the term for the consumer's anticipated regret.

In the market, an incumbent firm sells its product I of the durable good available in both periods. If a consumer buys product I at $t = 1$, she can use it for two periods. Besides, consumers are informed of characteristics and their valuation for this product (e.g., reviews for the incumbent's version help consumers to know the product or consumers can examine it in the store). All consumers' valuation of using product I for one period is denoted by v. Thus, if a consumer buys it at $t = 1$, her valuation for product I is $2v$, and if she buys it at $t = 2$, her valuation is v.

Besides the incumbent firm, an entrant can supply an improved version, product E, at $t = 2$. This version, in addition to all the features of the incumbent's one, includes some new features denoted by q_E, which are exogenous and public information. I assume that $q_E \leq v$ (new features are not more important than basic functionalities of this product). For instance, an improved version of electric vehicle may provide a longer travel distance on a single charge but this new feature is not

[5]Including a discount factor will only change restrictions on the existence of equilibrium and will not affect main results about regret.

[6]In section 5, I will discuss how the second-hand market affects consumers' purchase behavior and firms' profits.

more crucial than vehicle's core functionalities.[7] I also assume that marginal costs of production are zero and that there are no entry costs for the sake of simplicity.

To induce some consumers to wait for the version E, the entrant reveals q_E at the beginning of the game, which will be available at $t = 2$. However, I assume that at $t = 1$ there is no review or test for this product E. Hence, a consumer cannot fully assess whether she appreciates such new features q_E. Consumers only learn whether they appreciate new features q_E at $t = 2$, when the this version is available. Assume that a proportion $\phi \in [0,1]$ of consumers will appreciate new features, and it is public information. Thus, ϕ is also the ex-ante probability that a consumer will enjoy new features.

If a consumer appreciates new features, then her willingness to pay for new features q_E is denoted by θq_E, i.e., θ is the consumer's valuation for per unit of extra new features q_E. I assume that there is one unit mass of consumers, with characteristic θ, which is public information and uniformly distributed on $[0,1]$. Thus, ex-ante a consumer's valuation of entrant's good E is $v + \theta q_E$ with probability ϕ, and that is v with probability $(1-\phi)$. As a consequence, at $t = 1$, for a consumer of type θ, the ex-ante expected valuation for product E is $v + \phi\theta q_E$.

The prices for incumbent's version I in period t are denoted by p_{It}, where $t \in \{1,2\}$. The price p_{I1} is the initial price of the incumbent's version which is set before the entrant's decision on p_{E2}. The incumbent decides p_{I2} after the announcement of p_{E2} to serve some consumers who postpone purchasing. Both incumbent and entrant commits their prices at $t = 1$. In fact, whether price p_{I2} is set before or after p_{E2} will not influence the result. This is because even though the incumbent sets p_{I1} and p_{I2} simultaneously before the entrant's decision of p_{E2}, it can perfectly anticipate the entrant's behavior and decide p_{I2} in the same way as that in the initial setting.

The sequence of events is as follows and summarized in Figure 2.1: at the be-

[7] Assuming $q_E \leq v$ also allows me to reduce the equilibrium candidates and concentrate on the interesting results. Otherwise, all consumers may postpone consumption and there is no action regret.

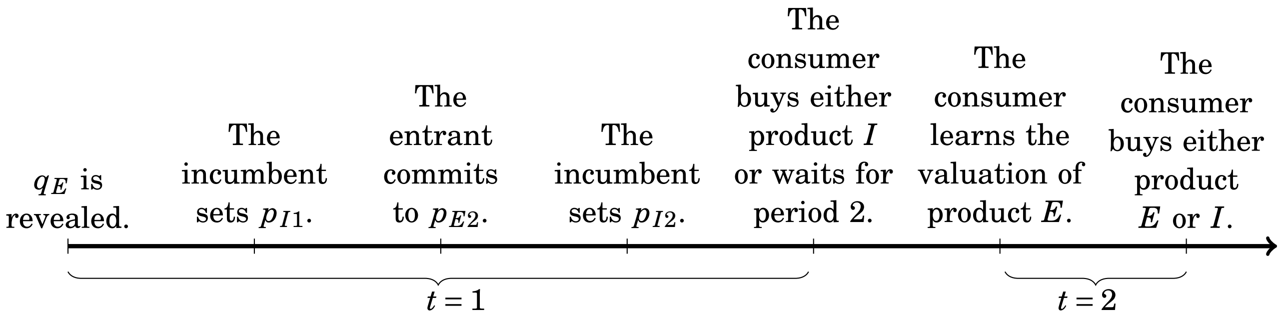


Figure 2.1: Timing

ginning of period 1, the entrant reveals the exogenous new features q_E. Then the incumbent decides the price of its product I for the first-period p_{I1}. The entrant observes this price and determines its price p_{E2} for product E for the second-period. Then the incumbent sets its price p_{I2} for the second period, to serve some consumers who will postpone the consumption. Consumers decide either to buy the incumbent's good I at $t = 1$. In the second period, all consumers learn whether they enjoy new features or not. Then at $t = 2$ remaining consumers decide whether to buy product I or E or not to buy any good. I solve this sequential game by backward induction.

Assumption 2.1. $\frac{13}{20} \le \phi \le 1$, $\frac{v}{3\phi} \le q_E \le v$.

Assumption 2.1 guarantees that in equilibrium the incumbent profits more from selling product I in both periods instead of setting a low price p_{I2} such that all consumers postpone purchasing. Moreover, it ensures that the entrant will enter the market. In addition, under Assumption 2.1 some consumers will wait for product E. Otherwise, the model is trivial since all consumers buy version I at $t = 1$, and the entrant will never enter the market. Assumption 2.1 highlights that a competitive entrant exists only if a consumer's probability of enjoying new features and the quality of new features q_E are high enough.

2.3 Benchmark: equilibrium without anticipated regret

As a benchmark, I consider the basic case where consumers do not anticipate any regret. Prior to presenting the outcome, I describe the process by which I obtain the equilibrium.

To study the consumer's purchasing decision, the utility is the key. The consumer's utility when she purchases the incumbent's version I at $t = 1$ and $t = 2$ are, respectively:

$$u_{I1} = 2v - p_{I1},\ u_{I2} = v - p_{I2}.$$

At $t = 1$, the valuation of the entrant's version E is not fully informed, a consumer with parameter θ enjoys the new feature with probability ϕ, in which case she will have ex-post utility $u_{E2} = v + \theta q_E - p_{E2}$. On the other hand, she does not enjoy them with probability $(1-\phi)$, and she will have utility $u'_{E2} = v - p_{E2}$. Thus, at $t = 1$ her expected utility of the entrant's product E is:

$$Eu_{E2} = v + \phi\theta q_E - p_{E2}.$$

A consumer can either buy product I at $t = 1$ and enjoy it for two periods or wait for $t = 2$ and decide at that time which version to buy. I assume that she will buy incumbent's version I if she is indifferent between buying two versions.

I begin by analyzing consumers' demand for any prices combination (p_{I1}, p_{I2}, p_{E2}). At $t = 2$, only consumers who have chosen to wait at $t = 1$ are in the market. Then ϕ proportion of remaining consumers realize they can utilize the new features contained in entrant's product E and have utility u_{E2} if they buy it. In this population, consumers with $u_{E2} \geq u_{I2}$ will buy entrant's product E at $t = 2$, that is, at $t = 2$ the demand for the entrant is formed by consumers with $\theta \geq \tilde{\theta}(p_{I2}, p_{E2}) = \frac{p_{E2}-p_{I2}}{q_E}$. Note that $\tilde{\theta}$ is well defined only if at least those consumers with $\theta \geq \tilde{\theta}$ have chosen to wait at $t = 1$. Otherwise, the consumer with $\tilde{\theta}$ has bought product I at $t = 1$ and all remaining consumers at $t=2$ who like new features of product E will buy it. Other consumers realize that new features are useless, and they have the same valuation for both versions and will buy the incumbent's product if $u_{I2} \geq v - p_{E2}$, that is, if $p_{I2} \leq p_{E2}$.

At $t=1$, consumers with $Eu_{E2} \geq u_{I1}$ wait for entrant's product E and remaining consumers buy incumbent's good I. Formally, the demand for product I at $t=1$ is those consumers with $\theta \leq \hat{\theta}(p_{I1}, p_{I2}, p_{E2}) = \frac{v - p_{I1} + p_{E2}}{\phi q_E}$. Clearly, $\hat{\theta}$ is the threshold at which the consumer is indifferent between buying the incumbent's product at $t=1$ and waiting for the entrant's good to be in the market. Note that it is always the case that $\hat{\theta} \geq \tilde{\theta}$.[8] All consumers with $\theta \leq \hat{\theta}$ buy the incumbent's good at $t=1$ and leave the market. Then, at $t=2$, the proportion ϕ of the remaining consumers like new features and buy the entrant's version E, and $(1-\phi)$ of remaining consumers do not enjoy that and buy incumbent's product I if its price is lower. In this case, as I mentioned $\tilde{\theta}$ is not well defined and will not be used in solving the model.

Now knowing the demand for products I and E in different periods, let us consider the incumbent's pricing strategy for its good at $t=2$. It will not set a price larger than the entrant's since all consumers at $t=2$ will buy the entrant's good whether they like new features or not. I show (in the Appendix) that in the equilibrium it is also not optimal for the incumbent to set a price lower than the entrant's. The reason is that under Assumption 2.1 it is not profitable for the incumbent to decrease p_{I2} such that some consumers at $t=2$ who appreciate new features decide to buy product I. Therefore, the incumbent matches the price of the entrant: $p^{\star}_{I2} = p_{E2}$, and it only serves consumers who realize that they do not enjoy new features at $t=2$. Then, $(1-\phi)(1-\hat{\theta})$ consumers will buy product I, and $\phi(1-\hat{\theta})$ consumers will buy entrant's good E at $t=2$.

Anticipating the incumbent's pricing strategy $p^{\star}_{I2}$, the entrant decides the op-

[8]Otherwise, $\hat{\theta} < \tilde{\theta}$ implies that $v - p_{I1} + (1-\phi)p_{E2} + \phi p_{I2} < 0$. Since $p_{E2} \geq p_{I2}$ such that $\tilde{\theta}$ is well defined, $0 > v - p_{I1} + (1-\phi)p_{E2} + \phi p_{I2} > v - p_{I1} + (1-\phi)p_{I2} + \phi p_{I2} = v - p_{I1} + p_{I2}$. Inequality $v - p_{I1} + p_{I2} < 0$ implies that $u_{I1} = 2v - p_{I1} < u_{I2} = v - p_{I2}$, which means that all consumers postpone purchasing, and this is not the case under Assumption 2.1. Such pricing strategy is not optimal for the incumbent and it is not the equilibrium. Thus, $\hat{\theta} \geq \tilde{\theta}$.

timal price p_{E2} to maximize its profit:

$$\max_{p_{E2}} \Pi_E = \max_{p_{E2}} \phi \int_{\frac{v-p_{I1}+p_{E2}}{\phi q_E}}^{1} p_{E2} d\theta.$$

The solution is $p_{E2}^\star = \frac{\phi q_E + p_{I1} - v}{2}$. The incumbent anticipates $p_{E2}^\star$, it decides the price p_{I1} taking into account $\hat{\theta} = \frac{v-p_{I1}+\phi q_E}{2\phi q_E}$ consumers buy its good at $t = 1$ at p_{I1}, and $(1-\phi)(1-\hat{\theta})$ consumers buy its good at $p_{I2}^\star = p_{E2}^\star$ at $t = 2$. The incumbent solves:

$$\max_{p_{I1}} \Pi_I = \max_{p_{I1}} \underbrace{\int_0^{\frac{v-p_{I1}+\phi q_E}{2\phi q_E}} p_{I1} d\theta}_{\Pi_{I1}} + \underbrace{(1-\phi)\int_{\frac{v-p_{I1}+\phi q_E}{2\phi q_E}}^{1} \frac{\phi q_E + p_{I1} - v}{2} d\theta}_{\Pi_{I2}},$$

where Π_{I1} denotes the incumbent's profit from $t = 1$, and Π_{I2} represents that from $t = 2$. Proposition 2.1 summarizes firms' equilibrium prices and expected profits when consumers do not anticipate any regret.

Proposition 2.1. *Under Assumption 2.1, in equilibrium:*
The prices are $p_{I1}^\star = \frac{\phi[(2-\phi)q_E+v]}{1+\phi}$, $p_{E2}^\star = p_{I2}^\star = \frac{3\phi q_E - v}{2(1+\phi)}$.
The demand for incumbent's version I at $t = 1$ is $\hat{\theta}^\star = \frac{v+(2\phi-1)\phi q_E}{2(1+\phi)\phi q_E}$.
The expected profits are $\Pi_I^\star = \frac{v^2+2(2\phi-1)\phi v q_E+(5-4\phi)\phi^2 {q_E}^2}{4(1+\phi)\phi q_E}$, $\Pi_E^\star = \frac{(3\phi q_E - v)^2}{4(1+\phi)^2 q_E}$.

From Proposition 2.1, for a given q_E, the prices $p_{I1}^\star$, $p_{I2}^\star$ and $p_{E2}^\star$ are strictly increasing in ϕ but $\frac{\partial \hat{\theta}^\star}{\partial \phi} < 0$. This is because, a greater ϕ means that there are more consumers who will utilize the new features and the ex-ante likelihood of using them are higher. More consumers will choose to wait for $t = 2$ (demand for product E is higher but $\hat{\theta}^\star$ is lower), thus, the entrant can increase p_{E2} while the incumbent will also raise its prices as the response. Additionally, the incumbent's profit $\Pi_I^\star$ strictly decrease, and the entrant's profit $\Pi_E^\star$ strictly increase in ϕ. On the other hand, for a given ϕ, q_E has a positive effect on the prices and the entrant's profit and a negative effect on the demand of product I at $t = 1$. However, the incumbent's profit may either increase or decrease in q_E: if new attributes are high enough, more precisely, when $q_E \geq \frac{v}{\sqrt{5-4\phi}}$, the incumbent's profit $\Pi_I^\star$ increase in q_E. The intuition is that an increase on this high level of q_E does not make the entrant much more competitive since there are already many consumers in the second period, the impact of the decrease in $\hat{\theta}^\star$ is dominated by that of the increase in its prices at $t = 1$ and $t = 2$, which yields a higher overall profits.

2.4 Consumer's anticipated regrets

In this section, I analyze impacts of consumers' anticipation of regret when making consumption decision at $t = 1$ since they are not fully informed of the valuation of new features that will be contained in product E. The way to solve the equilibrium is the same as that in the benchmark case. I begin by modeling consumers' regret and introducing it into the utility function.

The consumer would experience *action regret* at $t = 2$ if she bought incumbent's product I at $t = 1$, but afterwards she would appreciate the features of entrant's product E. For these consumers, the utility of the chosen alternative (u_C) is the utility of buying product I at $t = 1$: $u_C = 2v - p_{I1}$. The utility of the forgone alternative (u_F) is the utility of buying product E at $t = 2$: $u_F = v + \theta q_E - p_{E2}$. These consumers will experience regret if the utility of the forgone alternative is higher, which could make them better off, i.e., $u_F > u_C$.[9] To model regret, let us consider a linear regret term. Regret takes the form of the disutility $-r_a(u_F - u_C)$, where $r_a > 0$ is the consumer's sensitivity to action regret. In other words, r_a measures the consumer's feeling about regret. Remember that at $t = 1$, consumers' ex-ante probability of enjoying new features is ϕ, thus, those consumers with $u_F > u_C$ will experience action regret with probability ϕ.

One may consider that the consumer's probability of suffering regret may also depend on other parameters. For instance, only part of the population of consumers will have the feeling of regret. But the probability of experiencing anticipated regret for the rest of consumers still depends on the probability of enjoying new features,

[9]Note that some consumers who bought incumbent's good I at $t = 1$ and would enjoy new features would not experience regret. This is the case when $\theta \leq \frac{v+p_{E2}-p_{I1}}{q_E}$. Because even though they are fully informed of the valuation of the new attributes, and they like these features, buying incumbent's good I at $t = 1$ provides a higher utility.

which is ϕ because in the population ϕ of them will enjoy new attributes. In addition, it could be the case that some consumers never have the feeling of regret in the real world. I can include one parameter to capture this property; for instance, a proportion of the population has no sense of regret. Then by controlling this parameter under certain circumstances (e.g., it is high enough), I can obtain the same results. Therefore, to focus on the analysis of the effect of regret and to simplify the model, let us consider these consumers' probability of suffering action regret is exactly ϕ.

Then, when a consumer makes purchasing decision at $t = 1$, she anticipates action regret as an expected disutility for making the wrong decision,

$$-r_a\phi\max\{(u_F - u_C), 0\} = -r_a\phi\max\{[(v + \theta q_E - p_{E2}) - (2v - p_{I1})], 0\} \leq 0.$$

Thus, taking into account the disutility of anticipated action regret, the consumer's expected utility of choosing the incumbent's product I at $t = 1$ is

$$Eu_{I1}^a = 2v - p_{I1} - r_a\phi\max\{(\theta q_E - p_{E2} - v + p_{I1}), 0\}.$$

The other type of regret is *inaction regret*, which occurs when a consumer chose to wait for product E at $t = 1$, but afterward she would not enjoy new features at $t = 2$. Thus, she regrets not having bought incumbent's good I at $t = 1$. In this scenario, a consumer, who suffers inaction regret, either buys product I or product E at $t = 2$ depending on their prices. Thus, the utility of the chosen alternative (u_C) is the utility of buying product I or E at $t = 2$, formally, $u_C = v - \min\{p_{I2}, p_{E2}\}$. The utility of the forgone alternative (u_F) is the utility of buying incumbent's product I at $t = 1$: $u_F = 2v - p_{I1}$. Consumers experience inaction regret if $u_F > u_C$. Ex-ante, consumers anticipate that with probability $(1 - \phi)$ they will not utilize new functionalities of product E. Therefore, they expect to experience inaction regret with probability $(1 - \phi)$ if they choose to wait the product I when they are making the purchase decision at $t = 1$. I model the inaction regret also by using a linear term. When a consumer considers waiting for product E at $t = 1$, her expected disutility corresponding to the inaction regret is:

$$-r_i(1-\phi)\max\{(u_F - u_C), 0\} = -r_i(1-\phi)\max\{[(2v - p_{I1}) - (v - \min\{p_{I2}, p_{E2}\})], 0\} \leq 0,$$

where r_i is the consumer's sensitivity of anticipated inaction regret. As a consequence, taking this linear term into the consumer's expected utility function of waiting for product E at $t = 1$, formally:

$$Eu^i_{E2} = v + \phi\theta q_E - p_{E2} - r_i(1-\phi)\max\{(v - p_{I1} + \min\{p_{I2}, p_{E2}\}), 0\}.$$

In comparison to the benchmark scenario, it is intuitive that the anticipation of action regret makes consumers more reluctant to buy the incumbent's product in the first period. On the contrary, the influence of anticipated inaction regret is the other way around. To identify the impact of different types of regret, I will discuss two extreme scenarios: (1) $r_a > r_i = 0$ and (2) $r_i > r_a = 0$.[10]

2.4.1 Analysis of anticipated action regret ($r_a > r_i = 0$)

In this section, a consumer θ's utility functions for possible alternatives are:

$$Eu^a_{I1} = 2v - p_{I1} - r_a\phi\max\{(\theta q_E - p_{E2} - v + p_{I1}), 0\},$$

$$u_{I2} = v - p_{I2},$$

$$Eu_{E2} = v + \phi\theta q_E - p_{E2}.$$

Under Assumption 2.1, the equilibrium prices ($p^\star_{I1}$, $p^\star_{I2}$, $p^\star_{E2}$) and the demand $\hat{\theta}^\star$ are detailed in Claim B.1 in the Appendix for the sake of presentation. I summarize characteristics of them in Lemma 2.1.

[10]Consumers may anticipate both types of regret. I will discuss this possibility in Section 5. But we can anticipate that the influence of each type of regret on consumers' behavior and the firms' profits will be the same and final conclusion will be the combination of effects of regret in the two extreme cases.

Lemma 2.1. *Prices $p^\star_{I1}$, $p^\star_{I2}$ and $p^\star_{E2}$ increase in r_a, demand $\hat{\theta}^\star$ decreases in r_a.*

The anticipation of action regret will influence both the prices and the demand. A higher proportion of consumers is willing to wait for good E. Thus, the entrant will increase $p^\star_{E2}$ in order to obtain more profit. In equilibrium, prices of product I also increase in the regret sensitivity r_a in response to the increase of $p^\star_{E2}$. The demand $\hat{\theta}^\star$ is strictly decreasing in r_a since consumers are more reluctant to buy from the incumbent at $t = 1$. As can be seen in the Appendix, $p^\star_{I1} > p^\star_{I2}$, so for the incumbent, selling one unit of its product at $t = 1$ is more profitable than selling it at $t = 2$.

The equilibrium prices and the demand of the incumbent allow to obtain the two firms' profits in equilibrium:

Proposition 2.2. *Under Assumption 2.1, for any $r_a \in \mathbb{R}^+$, in equilibrium, profits are:*

$$\Pi^\star_I = \frac{(1+r_a\phi)^2v^2 + (5-4\phi)(1+r_a)^2\phi^2 {q_E}^2 + 2(2\phi-1)(1+r_a)(1+r_a\phi)\phi q_E v}{4(1+\phi)(1+r_a)(1+r_a\phi)\phi q_E},$$
$$\Pi^\star_E = \frac{[3(1+r_a)\phi q_E - (1+r_a\phi)v]^2}{4(1+\phi)^2(1+r_a)(1+r_a\phi)q_E}.$$

As a consequence of the effects of prices and demand (as shown by Remark B.1 in the Appendix), the incumbent's profit at $t = 1$ decreases in r_a and that at $t = 2$ increases in r_a. The effect of action regret on the overall profit depends on the change of profit in which period plays a dominant role. Proposition 2.3 shows how the regret sensitivity r_a affects the incumbent's and entrant's total profit under Assumption 2.1:

Proposition 2.3. *For the incumbent:*
(1) When $\frac{v}{3\phi} \le q_E \le \frac{v}{\sqrt{5-4\phi}}$, $\frac{\partial \Pi^\star_I}{\partial r_a} \le 0$.
(2) When $\frac{v}{\phi\sqrt{5-4\phi}} \le q_E \le v$, $\frac{\partial \Pi^\star_I}{\partial r_a} \ge 0$.
(3) When $\frac{v}{\sqrt{5-4\phi}} < q_E < \frac{v}{\phi\sqrt{5-4\phi}}$, there exists a threshold $\hat{r}_a = \frac{v-\phi q_E\sqrt{5-4\phi}}{\phi[q_E\sqrt{5-4\phi}-v]}$, such that if $r_a < \hat{r}_a$, $\frac{\partial \Pi^\star_I}{\partial r_a} < 0$ and if $r_a \ge \hat{r}_a$, $\frac{\partial \Pi^\star_I}{\partial r_a} \ge 0$.

For the entrant, it is always the case that $\frac{\partial \Pi_E^\star}{\partial r_a} > 0$. *In addition,* $\frac{\partial^2 \Pi_I^\star}{\partial r_a \partial q_E} > 0$ *and* $\frac{\partial^2 \Pi_E^\star}{\partial r_a \partial q_E} > 0$.

Not surprisingly, according to Proposition 2.3, the entrant's profit increases in r_a, and this positive impact is greater if q_E is higher since more consumers are in period 2 (i.e., $\frac{\partial^2 \Pi_E^\star}{\partial r_a \partial q_E} > 0$). More interesting, the anticipated action regret does not always harm the incumbent. Let me explain the intuition for the different cases. In case (1), when q_E is relatively low, the incumbent's profit decreases in r_a because the loss from the decrease in the incumbent's demand at $t = 1$, $\hat{\theta}^\star$, cannot be compensated by the gain from the increase of its prices. The action regret's effect on prices and $\hat{\theta}^\star$ implies that the decrease in the incumbent's profit at $t = 1$ is greater than the increase at $t = 2$. The curve in Figure 2.2(a) represents the incumbent's profit for the combination of the parameters ($v = 1$, $\phi = 0.7$, $q_E = 0.6$), which satisfies the restriction in case (1). But this negative effect is mitigated when q_E is larger. Because a stronger action regret increases profit of period 2, and a higher q_E gives the incumbent's profit of period 2 more weight in total profit, which implies a weaker negative effect from action regret on its profit of period 1 (i.e., $\frac{\partial^2 \Pi_I^\star}{\partial r_a \partial q_E} > 0$).

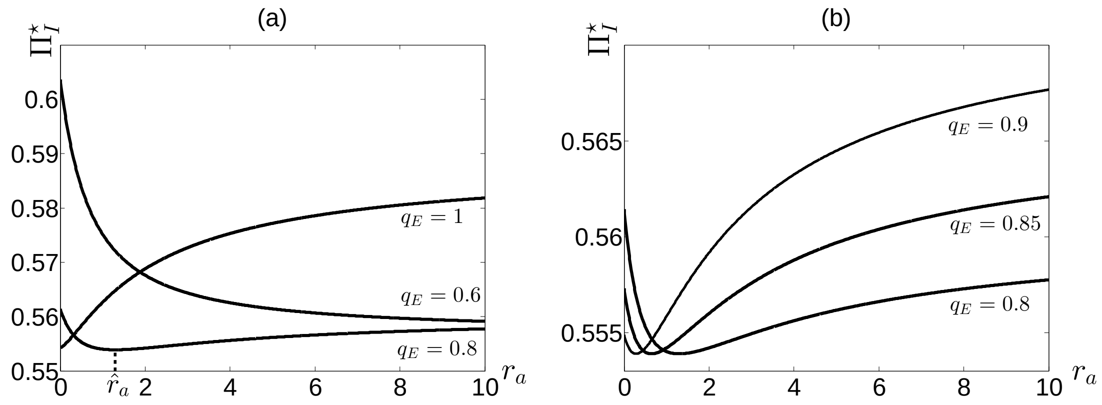


Figure 2.2: Illustration of the effect of action regret on the incumbent's profit for different levels q_E when ($v = 1$, $\phi = 0.7$).

In case (2), when q_E is high enough, the incumbent's profit is strictly increasing in r_a. A large q_E makes product E more attractive, which implies that the demand $\hat{\theta}^\star$ is already at a low level. Therefore, a higher action regret intensity will decrease

$\hat{\theta}^\star$ slightly. Since product I's prices at $t = 1$ and $t = 2$ increase in r_a, the combination of the two effects will increase the incumbent's overall profits. In other words, the increase in the incumbent's profit at $t = 2$ compensates the decrease in its profit at $t = 1$. This case is illustrated by the curve in Figure 2.2(a) with the parameter combination ($v = 1$, $\phi = 0.7$, $q_E = 1$). Besides, the higher q_E is, the stronger this positive effect will be since the incumbent's profit at $t = 2$ is more critical.

Case (3) shows that the incumbent's profit may have a U-form pattern with respect to the regret aversion r_a. If r_a is low, the effect of this variable on the incumbent's profit is the same as that in case (1). That is, the influence of the decline of $\hat{\theta}^\star$ dominates that of the rise of prices, which implies that the decrease in the profit at $t = 1$ is dominant. On the other hand, when r_a is high, its influence on the incumbent's profit is reversed. This result is illustrated by the profit curve in Figure 2.2(a) for ($v = 1$, $\phi = 0.7$, $q_E = 0.8$).

For completeness, I provide three U-shape examples in Figure 2.2(b) where $v = 1$ and I consider $q_E = 0.8$, $q_E = 0.85$, and $q_E = 0.9$. In particular, if q_E is high enough, this figure illustrates that the incumbent can be better off when action regret intensity is high enough compared to the non-regret case $r_a = 0$, of which the profit lies on the vertical axis. In addition, $\hat{r}_a$ decreases in q_E, which means that the incumbent's profit starts increasing from a lower r_a, and finally, it switches from scenario (3) to scenario (2). In addition, from Figure 2.2(b), the decrease part of the curve is flatter when q_E is higher, that is, the negative effect of action regret is mitigated by a higher q_E. The decrease on the profit curve when $q_E = 0.9$ is flatter than others. Meanwhile, when a stronger action regret increases the incumbent's profit, the curve is steeper when $q_E = 0.9$ than others, which means that a greater q_E strengthens the action regret's positive effect on the incumbent's profit.

To summarize, the relationship between the incumbent's profit and the consumer's action regret sensitivity varies depending on the level of new features q_E. Both companies may gain from consumers' increased sense of action regret, which is a win-win situation, and their profits may be even higher when consumers anticipate action regret than when they do not. Thus, the entrant is interested in reminding consumers about the action regret to increase its profit. For instance, advertising action regret may increase the regret intensity (i.e., consumers become more regretful about making a wrong purchase decision). Especially in the case where new attributes are relatively good, enhancing the anticipated action regret is a salient factor in strategy making for the entrant because action regret has an even stronger positive influence on its profit. Moreover, in this case, the incumbent may have no incentive to react to the entrant's advertising behavior because it also benefits from the consumer's anticipated action regret.

In the real-world, firms are undoubtedly aware of the impact of anticipated action regret on consumer's decisions, and they adopt strategies to benefit from action regret. Many advertisements from sellers of improved versions of products remind consumers about action regret, for example, the advertisement from Intel: "You can't rewind regret."[11] Such advertisements will benefit improved version sellers.

2.4.2 Analysis of inaction regret ($r_i > r_a = 0$)

When consumers anticipate potential inaction regret, their utilities for all possible alternatives of consumption are:

$$u_{I1} = 2v - p_{I1},$$

$$u_{I2} = v - p_{I2},$$

$$Eu^i_{E2} = v + \phi\theta q_E - p_{E2} - r_i(1-\phi)\max\{(v - p_{I1} + \min\{p_{I2}, p_{E2}\}), 0\}.$$

Assumption 2.2. $0 < r_i \leq \bar{r}_i = \frac{3\phi q_E - v}{(1-\phi)v}$.

Assumption 2.2 ensures that some residual demand exists for product E at $t = 2$. Anticipating inaction regret makes consumers more reluctant to wait for the entrant's good E, I assume inaction regret intensity is not too high. Otherwise,

[11]Advertisement: "Wish you'd bought the better PC?" (Intel).

the utility of waiting for it is extremely low, so that all consumers will buy the incumbent's good I at $t = 1$. Under assumption 2.1 and 2.2, the equilibrium prices $(p^{\star}_{I1}, p^{\star}_{I2}, p^{\star}_{I3})$, and demand $\hat{\theta}^{\star}$ are stated in Claim B.2 in the Appendix, and main properties are summarized in following Lemma 2.2.

Lemma 2.2. *The prices $p^{\star}_{I1}$, $p^{\star}_{I2}$ and $p^{\star}_{I3}$ decrease in r_i, the demand $\hat{\theta}^{\star}$ increases in r_i.*

The incumbent will set $p^{\star}_{I2} = p_{E2}$, which is similar to that in the previous case. Prices strictly decrease in the regret aversion r_i and convex, and $\hat{\theta}$ linearly increases in r_i. When consumers anticipate inaction regret, the entrant has to decrease the price of product E to induce some consumers to wait for it. The incumbent will also decrease its prices expecting a lower p_{E2}.

The equilibrium prices and demand allow to obtain the firms' profit in equilibrium:

Proposition 2.4. *Under Assumption 2.1 and 2.2, in equilibrium, the firms' profits are:*

$$\Pi^{\star}_{I} = \frac{[1+(1-\phi)r_i]^2 v^2 + 2(2\phi-1)[1+(1-\phi)r_i]\phi v q_E + (5-4\phi)\phi^2 q_E{}^2}{4[1+(1-\phi)r_i](1+\phi)\phi q_E},$$
$$\Pi^{\star}_{E} = \frac{[3\phi q_E - (1+(1-\phi)r_i)v]^2}{4(1+\phi)^2[1+(1-\phi)r_i]q_E}.$$

As a consequence, a stronger intensity of inaction regret always increases the incumbent's profit at $t = 1$ but decreases that at $t = 2$ (which are stated in Remark B.2 in the Appendix for the sake of presentation). The effect of anticipated inaction regret on the firms' total profits are stated in Proposition 2.5.

Proposition 2.5. *Under Assumption 2.1 and 2.2, for the incumbent:*
(1) When $\frac{v}{3\phi} \le q_E \le \frac{v}{\phi\sqrt{5-4\phi}}$, $\frac{\partial \Pi^{\star}_{I}}{\partial r_i} \ge 0$.
(2) When $\frac{v}{\phi\sqrt{5-4\phi}} < q_E \le v$, *there exists a threshold* $\hat{r}_i = \frac{\phi q_E\sqrt{5-4\phi}-v}{(1-\phi)v} < \bar{r}_i$ *if* $r_i \le \hat{r}_i$, $\frac{\partial \Pi^{\star}_{I}}{\partial r_i} \le 0$, *if* $r_i > \hat{r}_i$, $\frac{\partial \Pi^{\star}_{I}}{\partial r_i} > 0$.
For the entrant, its profit always decreases in r_i. In addition, $\frac{\partial^2 \Pi^{\star}_{I}}{\partial r_i \partial q_E} < 0$ *and* $\frac{\partial^2 \Pi^{\star}_{E}}{\partial r_i \partial q_E} < 0$.

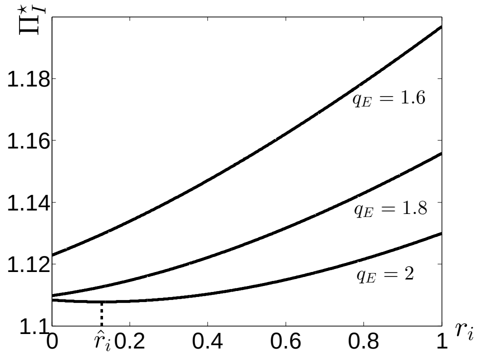


Figure 2.3: Illustration of the effect of inaction regret on the incumbent's profit for different levels q_E when ($v = 2$, $\phi = 0.7$).

The incumbent's profit always increases in the regret aversion parameter r_i when q_E is not too high as shown in case (1). The logic is that when the entrant's product is not too competitive, it has to set its price low enough, and the incumbent will also set relatively low prices for its version I. For a higher r_i, the negative effect on the prices is weak since the entrant cannot decrease its price that much. Meanwhile, the demand for product I at $t = 1$, $\hat{\theta}$, strictly increases in r_i. The combination of effects of prices and demand implies that the increase in the incumbent's profit at $t = 1$ is greater than the decrease in its profit at $t = 2$, which yields a higher overall profit. This increase in profit is illustrated by the profit curves in Figure 2.3 when ($v = 2$, $\phi = 0.7$, $q_E = 1.6$ and $q_E = 1.8$). From this figure and analysis, a higher q_E weakens the positive effect of anticipated inaction regret. The profit curve when $q_E = 1.6$ is steeper than when $q_E = 1.8$. Because a greater q_E increases the incumbent's profit at $t = 2$ as well as its weight in overall profit. A stronger inaction regret will reduce profit at $t = 2$, thus, a greater q_E will weaken the positive effect of inaction regret on the total profit (i.e., $\frac{\partial^2 \Pi_I^\star}{\partial r_i \partial q_E} < 0$).

Case (2) describes the situation where the incumbent's profit has a U-form as a function of r_i as the profit curve shown for ($v = 2$, $q_E = 2$) in Figure 2.3. The intuition is that when q_E is high enough, the incumbent's prices decrease considerably in r_i for low values of r_i, that are not compensated by the increase in the demand $\hat{\theta}^\star$. These effects imply a larger decrease in the incumbent's profit at $t = 2$ and a decrease in total profit. In contrast, for high r_i (i.e., $r_i > \hat{r}_i$), the decrease in prices is slight, and the demand increases linearly. In this case, the incumbent's profit increase in r_i, and the reason is the same as that in the case (1). Since $\frac{\partial^2 \Pi_I^\star}{\partial r_i \partial q_E} < 0$, a higher q_E strengthens the decrease of the incumbent's total profit since the decline of profit at $t = 2$ is even more crucial.

On the other hand, the entrant's profit decreases in r_i when consumers experience anticipated inaction regret because of lower price and demand. Moreover, this negative impact is stronger when q_E is higher. Because a higher q_E implies more profit at $t = 2$ for the entrant thus, a stronger intensity of inaction regret will decrease this profit more than the case when q_E is lower.

Consequently, consumers' anticipated inaction regret may simultaneously decrease both firms' profits, resulting in a lose-lose situation. Therefore, when new functionalities from the improved version are of high quality, both firms may try to let consumers ignore the potential inaction regret. Nevertheless, when new attributes are lower, the incumbent always benefits more from potential inaction regret. In this scenario, it wants to advertise the inaction regret.

2.5 Extensions and discussions

In the previous section, I investigate the effects of action regret and inaction regret separately. In this section, I discuss the robustness of my results in different setups.

2.5.1 Consumers anticipate both types of regret

When consumers anticipate both types of regret, that is, where ($r_a > 0$, $r_i > 0$), I expect that action regret and inaction regret cannot be beneficial for the incumbent or the entrant simultaneously since they have opposite effects. Without solving all possible cases I studied in Section 4, let me concentrate on the analysis of the situation where the effect of one type of regret dominates the other. To this aim, I include additional Assumption 2.3 guaranteeing that both firms are active in the market in this new setup.

Assumption 2.3. $0 \le r_i \le \frac{3\phi(1+r_a)q_E-(1+\phi r_a)v}{(1-\phi)v}$.

Proposition 2.6. *Under Assumption 2.1 and 2.3:*

(a) For any r_i, the action regret has a larger impact on the incumbent's profit, that is, $|\frac{\partial \Pi_I}{\partial r_a}| \ge |\frac{\partial \Pi_I}{\partial r_i}|$, if and only if $r_a \le \frac{\phi}{(1-\phi)}$.

(b) The action regret has a greater effect on the entrant's profit, that is, $|\frac{\partial \Pi_E}{\partial r_a}| \ge |\frac{\partial \Pi_E}{\partial r_i}|$, if and only if $r_a \le r_i$.

Proposition 2.6 shows that when the two types of regret are present, the effect of action regret dominates the inaction regret on the incumbent's profit when regret r_a is not too high. On the other hand, action regret has a higher effect on the entrant's profit if r_a is lower than r_i. The intuition comes from the fact that the effect of regret on the firms' profits is not linear, and when action regret is low, its effect is much stronger than the effect of inaction regret. For the entrant, if the action regret level is greater than inaction regret, it may need to advertise more about action regret to compensate the higher negative effect from the inaction regret.

2.5.2 The incumbent offers a free (minor) upgrade at $t = 2$

In this subsection, I consider that at $t = 2$, the incumbent has a minor technology upgrade on its product I, which is denoted by q_I and I assume $q_I < q_E$.[12] Such an improvement may allow the incumbent to reduce the negative effect of regret. I assume that q_I is exogenous and publicly known. At $t = 1$, the incumbent may commit to providing a free upgrade at $t = 2$ to consumers who have bought product I at $t = 1$ and those who would buy it at $t = 2$. For instance, electric vehicle companies may provide a free upgrade for the vehicle's battery, and software companies always provide a free upgrade for consumers who have already bought their initial version.

[12] I assume that the upgrade from the incumbent is not better than new features of product E. Otherwise, all consumers will buy incumbent's product I at $t = 1$, and there is no inaction regret which is the case that I want to avoid.

I introduce a new assumption similar to Assumption 2.1 and 2.2 to guarantee the existence of the interesting case:

Assumption 2.4. $\frac{13}{20} \le \phi \le 1$, $\frac{v}{3\phi} \le (q_E - q_I) \le v$ *and* $0 < r_i \le \bar{r}_i = \frac{3\phi(q_E - q_I) - v}{(1-\phi)v}$.

Assumption 2.4 guarantees that some consumers are willing to wait for product E. Proposition 2.7 relates the effect of offering a free upgrade with the effects associated to regret.

Proposition 2.7. *When the incumbent offers a free upgrade, this effect on firms' profits is the same as the one of inaction regret, and the opposite to the effect of action regret.*

The intuition is the following. A free minor upgrade increases the market competitiveness of the incumbent's version I, and more consumers will purchase it at $t = 1$. As a consequence, the entrant has to decrease its price to induce some consumers to wait for its improved version E. The upgrade can boost the positive effect of inaction regret. But the effect of it is the opposite of action regret. Thus, if the action regret harms the incumbent, it may consider introducing the free upgrade to reduce the negative effect. While the entrant's new qualities are of good quality, the incumbent's profit also increases in action regret intensity, and the incumbent has no incentive to introduce the minor upgrade.

2.5.3 A simple *k*-period model

I have investigated a two-period model. This section discusses the situation where the durability of the incumbent's product is k periods long, and product E's duration is $(k-1)$ periods. Similar to Assumption 2.2, I introduce the assumption for this scenario:

Assumption 2.5. $0 < r_i \le \frac{3\phi q_E(k-1) - v}{(1-\phi)v}$.

Given Assumption 2.1 and 2.5, as that in previous sections, I solve for the equilibrium prices, demand, and profits, and I obtain that prices are increasing in k, the demand for incumbent's product I at $t = 1$ is decreasing in k.[13]

Proposition 2.8. *The influence of a longer duration of the good on firms' profits is similar to that of action regret, and the opposite to the inaction regret's effect.*

The longer duration of the good raises the product's value. Especially for product E, as it has additional capabilities that may be utilized for $(k-1)$ periods. Hence, it is intuitive that extending the durability always enhances the entrant's profit since it results in a higher price and more demand for product E. Similarly, considering the incumbent's profit, a longer duration is comparable to action regret. Thus, if consumers have a strong feeling of inaction regret, which is detrimental to the entrant, a longer duration may reduce this adverse influence on the entrant's profit.

2.5.4 The discussion of a second-hand market and the arrival of new consumers

In my model, I do not consider the existence of a second-hand market. Nevertheless, we can anticipate that a second-hand market will mitigate the impact of regret on consumer purchasing decisions. A second-hand market will incentivize more consumers to buy the initial version I at $t = 1$ because they can resell it in the second period and buy the entrant's good E if they like new attributes. Hence the incumbent's profit at $t = 1$ may increase. However, the second-hand market will behave as a competitor to the incumbent at $t = 2$. Thus, the incumbent's profit at $t = 2$ could be lower. In total, the incumbent's profit may be either higher or lower, depending on the profit from each period.

I ignore the possibility that new consumers may arrive at the market at $t = 2$. Now imagine that a proportion of these new consumers enter the market at $t = 2$, some of whom also like new features, while others do not. The arrival of new con-

[13]The expressions of the prices, demand, and profits at equilibrium are in the Appendix.

sumers benefits the entrant since some buy its good at $t = 2$. Then, because the entrant is less concerned with profit from the initial customers, additional consumers may drive the entrant to establish a higher price p_{E2}. If the new consumer population is large, an extreme scenario may exist in which the entrant sets the price only based on the new arrivals' values, without attempting to attract any original consumer from $t = 1$. If the number of new consumers is not that high, I may have similar results to those in the initial model.

2.6 Conclusions

This paper investigates the effects of anticipated regret on consumers' behaviors and firms' profits in a duopoly durable good market. I discuss when firms profit from manipulating the consumer's regret sensitivity by advertising or other activities. In addition, I also provide solutions to mitigate the effect of regret when it is harmful to firms.

Action regret is always beneficial for the entrant, and inaction regret is always harmful. More interestingly, action and inaction regret may increase or decrease or have a U-shape effect on the incumbent's profit, depending on the intensity of the regret aversion and the quality of new features. Additionally, the quality level of new attributes from the entrant's product may either strengthen or weaken the influence of anticipated regret.

Consumers may anticipate both types of regret. My analysis of the two extreme cases allows me to understand this scenario. I show that the entrant profits from reminding consumers about their potential action regret to enhance this feeling over inaction regret. The conclusion about the incumbent is complicated because the influence of regret on its profits has different possibilities. That is, the incumbent's profit may increase or decrease in both types of regret. Considering the influence of anticipated regret, action regret may lead to a win-win situation for both firms, and inaction regret may cause a lose-lose scenario.

Nevertheless, according to different levels of new attributes contained in the entrant's improved version, both firms' strategies of playing up consumers' anticipated regret vary. When new attributes are high quality, the entrant always tries to enhance consumers' action regret, and the incumbent also benefits from that. Thus, the incumbent firm may not react to the entrant's behavior of reminding consumers about action regret. But when new attributes are of low quality, a stronger feeling of action regret will harm the incumbent, it may try to strengthen consumers' inaction regret or introduce a free minor upgrade as a reaction to mitigate the negative effect, which will reduce the entrant's profit.

Future research may discuss the advertising strategy and the influence of new arrival of consumers. I have mentioned that firms may try to use advertisements to enhance consumers' regret intensity but I have not discussed the optimal level of advertising when it is costly. Considering my previous discussion, the entrant has to anticipate the incumbent's reaction when it advertises action regret and then decides the strategy. On the other hand, as I have discussed in the previous section, new consumers in the market may have significant impact on firms' pricing and regret-reminding strategy. Further investigation on this aspect may be interesting.

Chapter 3

Similar-to-me effects in the grant application process: Applicants, panelists, and the likelihood of obtaining funds

3.1 Introduction

Many organizations rely on panels or committees to evaluate applications and candidates in merit-based selection procedures. Funding agencies, for instance, rely on peer review panels to judge the quality of grant applications. In such merit-based selection procedures, the individual probability of success should depend on the characteristics of the applications but not on the characteristics of the panels. Panels, however, may have different levels and types of expertise, views about the requirements, and/or preferences for particular types of applicants. All of this may affect panels' evaluations and decisions, thereby generating a "luck of the reviewer draw" for the applicants or for particular types of applicants (S. Cole et al., 1981).

This paper analyses if and how the characteristics of the grant research panels affect the applicants' likelihood of obtaining funding and, especially, if particular types of panels favour particular types of applicants. We study if some types of panels are tougher than others and if the applicants' connections to the panel influence their likelihood of success. But our focus is to understand if, conditional on all this, there exist "similar-to-me" effects in the grant selection process. According to this hypothesis, tested primarily on the labor market context, applicants will be rated more favorably the more similar they are to the rater (Byrne, 1971). We test if the individual probability of success depends on the similarities of the applicants and the grant evaluation panel in several research-related and demographic attributes.

We make use of the award decisions of one of the major public funding organizations for scientific research worldwide, the UK's Engineering and Physical Sciences Research Council (EPSRC). Our dataset includes the EPSRC applications and panels between 2000 and 2007. We obtain prior publication data of the teams of applicants and panelists and some of their personal attributes. We use this information to construct variables reflecting research-related (research quality and orientation) as well as demographic characteristics (affiliation to an elite Russell-group university, the ratio of females, and the presence of members of an Asian origin) of the team of applicants on one side, and of the panels, on the other. We base our choice of drivers of applicant success on previous literature (e.g., Grimpe, 2012) and build equivalent variables for the panels to perform a systematic two-sided comparison.

As a starting point, we first introduce in the analysis, and document the effects on the probability that a project is awarded funding of, the characteristics of the team of applicants as well as of the panels. Our results on the applicant characteristics are broadly consistent with those of previous literature (e.g., Grimpe, 2012 Banal-Estañol et al., 2019a, 2019b). As one would expect, the probability of success is higher for more accomplished applicants. In terms of magnitude, a one standard deviation increase in the applicants' research performance increases the probability of success by 2.1% or 7.1% of the unconditional probability of success. Moreover, more applied-oriented teams, those who do not belong to an elite university, and those that include more women and members of Asian origin are less successful.

We find that panel characteristics are also important. More accomplished panels are more demanding, but those with more members affiliated to an elite university are not. In terms of magnitude, a one standard deviation increase in panel's research performance decreases the probability of success by 2.6% or 8.6% of the unconditional probability of success. This effect, in absolute value, is stronger than the one of the applicants. Panels with more female members and those that include members of Asian origin are also less likely to award grants. The results on tougher female panelists are consistent with those of the few papers that analyse the effects of panel characteristics (Jayasinghe et al., 2003, and Tamblyn et al., 2018). Except for gender, we know relatively little about the role that the characteristics of the panels play in funding decisions.

We also control for the links between applicants and panels. We find that applicants benefit from having experience as a panelist. This is akin to the result of Viner et al. (2004), who, using data from the EPSRC, associate success in securing grants with experience in the peer review system. But we do not find evidence of "nepotism." Indeed, the likelihood of success does not change if the affiliation of the panel members coincides with that of the applicants or with the universities where the applicants earned their Ph.D. This contrasts with the few existing results on nepotism through institutional ties. Wold and Wennerås (1997), as well as Sandström and Hällsten (2008), show that applicants sharing an institutional affiliation with the panels were more likely to be successful in the award decisions of the Swedish Medical Research Council.[1]

Our main analysis shows that the effects of the characteristics of the applicants differ by the type of panel evaluating their application. Distinguishing panels by prior research performance, we show that the quality of the applicants is more critical for panels of "top" quality than for panels of relatively lower quality. In terms of magnitudes, a one standard deviation increase in the applicants' research performance increases the probability of success by 11.0% of the unconditional probability

[1] Nepotism through family ties, or more generally favoritism, in academic recruitment and promotion, has received more attention in the literature (see, e.g., Allesina, 2011, and Durante et al., 2009).

of success if evaluated by a top panel whereas it is increased by just 4.3% of the unconditional probability of success if evaluated by a non-top panel. Distinguishing between "applied" and non-applied "basic" research-oriented panels, we show that the degree of appliedness of the applicants decreases the chances of success for the basic but not for the applied panels. Finally, we classify the panels based on the personal attributes of their members, e.g., "female/non-female" and "Asian/non-Asian." Our analysis indicates that non-female panels tend to penalise female applicants, whereas female panels do not. Non-Asian panels also tend to discriminate against Asian applicants, whereas Asian panels do not. As a sole dimension that does not provide full support for our main hypothesis, Russell panels do not tend to favour teams from the Russell group of universities more than the non-Russell panels do.

Therefore, our results suggest that, generally, panel members favour more (or penalise less) applicants with similar characteristics to them, as the similar-to-me hypothesis suggests. A preference-based social psychology theory supports the similar-to-me hypothesis. There are two arguments: self-categorization (Turner et al., 1987) and similarity-attraction (Byrne, 1971). According to the self-categorization paradigm, our self-concept is based upon the social categories we place ourselves in (e.g., gender, race), and we desire to have a positive self-identity. The need for a positive self-identity causes us to prefer and evaluate more positively those similar to us on the social category on which we base our identity. This theory may explain the similar-to-me effects we find for gender and race. Although research-related characteristics may not be considered standard social categories, broad categories (based, for instance, on research performance or orientation) may also be self-descriptive and thus serve as useful social categories that are important in describing the self and others.

According to the similarity-attraction paradigm, an affective response (e.g., interpersonal attraction or liking) mediates the relationship between similarity and evaluation. Similarity can be actual or perceived, whereby the latter refers to the similarity a particular individual infers between oneself and an interaction partner. Both actual and perceived similarity effects on key traits, values, and/or beliefs have been previously demonstrated in studies of interpersonal attraction in human resource decisions (e.g., selection decisions). For instance, Ferris and Judge (1991) argue that perceived similarity may come into play because decision-makers act upon their perceptions of reality. Therefore, judgments of similarity may require some degree of cognitive interpretation (e.g., the rater perceives the applicant as similar in the research orientation) before an affective attraction can ensue (Srull and Wyer, 1989). In this sense, the elite/non-elite Russell group categorization may be less clear for the academic researchers than the other categorizations we use in the paper.

Our paper contributes to the literature that studies how the likelihood of being funded in a merit-based selection procedure depends on the characteristics of the applicants and those of the panel members. Except for gender, we know relatively little about the role that the characteristics of the panel play in funding decisions.[2] Likewise, very few papers have analysed the effects of cross-variables of applicants and panel members. Furthermore, and to the best of our knowledge, only Jayasinghe et al. (2003), Tamblyn et al. (2018), and Li (2017) have results on which type of panels favour which type of applications. Jayasinghe et al. (2003), using data from the Australian Research Council grants, do not find significant effects of the interaction of the applicant and assessor gender. Using Canadian health research grant applications, Tamblyn et al. (2018) find that reviewers with more expertise are more likely than those with less expertise to provide higher scores to applicants with higher past success rates. Li (2017), using data from the US National Institutes of Health, finds that increased relatedness between applicants

[2] A more extensive literature has analyzed the effects of the characteristics of the applicants. Grimpe (2012), for instance, shows that obtaining German grants is often not influenced by publication or patent stock but by other personal, institutional, and discipline characteristics. Banal-Estañol et al. (2019a, 2019b) show that scientific performance and institutional eminence are important determinants of success in EPSRC grants, whereas more applied academics find it more difficult to obtain financing. Tamblyn et al. (2018) find that grant applicants to the Canadian Institutes of Health with a higher h-index get higher scores. In contrast, female applicants and applicants in the applied sciences get lower scores. Jayasinghe et al. (2003) find that those from more prestigious universities received higher ratings, whereas female researchers receive lower ratings than male researchers in science. Viner et al. (2004) suggest that factors other than the quality of the research influence outcomes. They identify, in particular, biases against women and non-white groups. Wold and Wennerås (1997) also find evidence of gender bias in grant applications to the Swedish Medical Research Council.

and panelists, measured by cross-citations, raises the applicants' chances of winning a grant.[3] But, to our knowledge, the "similar-to-me" hypothesis has not been systematically tested in the grant application process.

This paper also contributes to the empirical literature that tests for "similar-to-me" effects in evaluation and selection procedures. Most of the existing evidence on these effects is in the context of the labor market selection process. Moreover, most of this literature has focused on readily detectable demographic dimensions, such as race (e.g., Prewett-Livingston et al., 1996) or gender (e.g., Bagues and Esteve-Volart, 2010), rather than on less visible functional dimensions that are more job-related, such as the research-related attributes in academia. Two exceptions in this sense are Hamermesh and Schmidt (2003) and Bagues and Perez-Villadoniga (2012), who examine the election of Fellows of the Econometric Society based on the research area and the entry to the Spanish Judiciary based on the area of expertise, respectively.[4]

The rest of the paper is organised as follows. Section 3.2 describes the data sources and the variables constructed. It also includes the descriptive statistics. Section 3.3 presents the effects of the research and personal characteristics of the team of applicants and the panel members on the probability of a project being funded. Section 3.4 studies how the resemblance between the characteristics of applicants and panel members may affect the likelihood of success. Finally, Section 3.5 concludes.

[3] Criscuolo et al. (2017) study the influence of the panel characteristics on the novelty of the R&D project selected among those submitted by employees of a large, multinational engineering consulting company. They find that whether the applicant and a panel member work at the same office does not affect the likelihood of funding a novel project, while the panel expertise diversity increases the likelihood of funding novel projects.

[4] The human resource literature does not always support the similar-to-me hypothesis. Bagues and Esteve-Volart (2010) and Zinovyeva and Bagues (2015) find that female candidates are less likely to be hired and promoted when the randomly assigned selection committee has a higher percentage of female evaluators. Bagues, Sylos-Labini, and Zinovyeva (2017) show that a larger number of women in evaluation committees does not increase the quantity or the quality of female candidates who qualify in the competitions to professor positions in Spain and Italy. On ethnicity, Bursell (2007), using Swedish data on job applications, finds that the applicants with a Swedish-sounding name are more likely to receive a call-back if the CEO has a foreign-sounding name than if s/he has a Swedish-sounding name.

3.2 Data, variables and descriptive statistics

We make use the award decisions of the EPSRC, the main UK government agency for funding research in engineering and the physical sciences. Our data emanate from all the EPSRC grant applications from 2000 to 2007 (both included), from which we build variables describing the applicant teams, the evaluating panels, and the award decisions. We now describe in detail the EPSRC process, the data sources, the variables we use in the analysis, and their main descriptive statistics.

3.2.1 The EPSRC process

The EPSRC relies on peer review panels to judge the quality of applications competing for funding. The EPSRC peer review panels are responsible for placing the applications in a funding priority order, based on which the final funding decision is made. An internal EPSRC “program manager" uses this priority list to decide how many proposals they can support with the available funding. Panels have around ten members whose expertise reflects the area of the research proposals being considered. The composition of the panels is not known ex-ante by the applicants, so it is not possible for them to self-select into a specific panel.

The EPSRC process includes a “postal peer review" stage, which consists in sending the application, together with a reviewer form, to several people to review, make comments, and provide a score for the application. The selection of reviewers is the responsibility of an internal “portfolio manager" of the EPSRC. The reviewer forms are part of the information used by the panel to decide where the proposal will be positioned on the rank order list and ultimately to whether the proposal is funded. Each proposal is considered sequentially, and the panel members must agree on the final score for ranking.

The EPSRC has a policy of identifying and avoiding conflicts of interest. Conflicts of interest occur if an individual involved in the assessment of a proposal has a personal or organisational relationship with the applicants that calls into question her/his ability to undertake her/his role in an objective and unbiased way. Panel members need to identify the conflicts of interest, and the conflicted member is asked to leave the meeting when that conflicted proposal is discussed.

3.2.2 Data sources

For each application, the EPSRC records contain the name of the principal investigator (the PI) and the coinvestigators (the other team members), the start and end dates, the holding organization of the grant, and the amount of funding requested. The PI must be an academic from a UK organization. In almost all the applications, the PI and the co-investigators are employees of the same holding organization. We also know whether the application has been funded or not, as well as the name and the affiliation of each of the panel members who took the funding decision on that specific application. Unfortunately, we do not have information on the application grades or other details of the decision.

All the EPSRC grant applications are matched with the academic calendar census data of all the engineering departments of the 39 major universities in the UK (see Banal-Estañol et al. (2015), for details). Our sample includes the applications that contain at least one academic engineer of the calendar database as a PI or as a co-investigator. We discard the applications of teams of more than 10 academics so that individual characteristics matter, but the results are very similar when we include all the proposals (only 1.5% of the applications involve more than 10 academics). Our final sample has $7,189$ applications over 8 years (2000-2007), which include at least one researcher with complete information.

We use prior publication data to identify research-related attributes of applicants and panelists. For each of them, we identify all their publications in the Web of Science (WoS) five years before the application date. For each of these publications, we identify (i) the number of citations received by December 2007 and (ii) the publishing journal's orientation category in the Patent Board classification (defined by Narin et al., 1976, and Hamilton, 2003).[5] This information allows us to proxy for a given researcher's research quality and orientation, respectively, at the time of the grant application.

We also obtained personal attributes of the applicants and panelists. The EP-SRC database allows us to determine whether they work at one of the prestigious set of universities of the Russell Group. We identified the gender from the given names and their personal web pages (searching for the given name and affiliation). We also identified whether they are of Asian origin from the 200 most common Asian family names, complemented by a manual check.[6] Finally, we obtained information on the Ph.D. granting institution of each applicant, using specialized websites (*ethos.bl.uk/Home.do* and *www.theses.com*) and their web pages.

3.2.3 Variables

We now provide a definition of the dependent and independent variables that we use to explain the likelihood of obtaining funding. We base our choice of variables on the applicant characteristics in previous literature (e.g., Grimpe, 2012 and Banal-Estañol et al., 2019a) and build equivalent variables for the panel members. We describe, in turn, applicant and panel member characteristics, cross-variables, controls, and the variables that are going to allow us to classify the types of panels. Table 3.1 provides a summary of all the variables.

Dependent variable Our binary dependent variable takes a value of 1 if the application was awarded funding and 0 if it was not.

[5] Citations are generally accepted as scientific merit since they measure the impact of the research results on other scientists (Bornmann and Daniel, 2005, J. R. Cole, 2000, and Tijssen et al., 2002).

[6] Asian researchers have significant contributions to engineering and the physical sciences. To identify this ethnic minority group in UK, we follow Lauderdale and Kestenbaum (2000) and Shah et al. (2010) and use South Asian, Chinese, Korean, and Japanese surnames.

Table 3.1: **List of variables**

Name of the variable	Definition of the variable
Award	dummy equal to 1 if the application is awarded
Applicant's characteristics	
Acad Quality app	annual normalized citations of papers published by the applicants divided by 10
Applied Orient app	ratio # of papers category 1 / # of papers all categories of papers published by the applicants
Russell Gr app	dummy equal to 1 if the host institution of the proposal is a uni in the Russell group
Ratio Female app	ratio # of women in the team/ # of total researchers in the team
Asian app	dummy equal to 1 if there is an Asian in the team
Panel's characteristics	
Acad Quality pan	annual normalized citations of papers published by the panelists divided by 10
Applied Orient pan	ratio # of papers category 1 / # of papers all categories of the papers published by the panelists
Russell Gr pan	dummy equal to 1 if the panel has a % of Russell members Group larger than the median panel
Ratio Female pan	ratio # of women in the panel/ # of total researchers in the panel
Asian pan	dummy equal to 1 if there is at least one Asian member in the panel
Cross variables	
Experience as Panelist	dummy equal to 1 if an applicant in the team has experience as panelist before the application
Connection as Colleague	dummy equal to 1 if there is a member in team and a panel member from the same university
Connection as Pre-doc	dummy equal to 1 if there is a team member who did the phd in a panel member's university
Controls	
Size Team app	sum of the # of coinvestigators and the PI in the team of the project
Size Team app sq	"Size Team app" squared
Size pan	sum of the # of members in the panel
Size pan sq	"Size pan" squared
Duration	duration of the project (in years)
Funds per cap	ratio of requested funding / # of members of the team (in millions)
Fraction Awarded	fraction of money awarded within a given quarter
Types of panels	
Top pan	dummy equal to 1 if panel's citation in first quartile of the distribution of "Acad Quality pan"
Applied pan	dummy equal to 1 if panel's applied orientation above the median panel
Russell Gr pan	dummy equal to 1 if the panel has a % of Russell Group members larger than the median panel
Female pan	dummy equal to 1 if the ratio of women in a panel above the median panel
Asian pan	dummy equal to 1 if there is at least one Asian member in the panel

Applicant characteristics We construct vertical and horizontal research-related measures of the applicants. To build a vertical measure of research quality, we count the number of "normalized" citations of each researcher's publications in the five years before the application. The normalized number of citations of a given publication is obtained by dividing the number of citations received by that publication by the average number of citations received by all the papers published in the same year and the same field as that publication. We define the variable *Acad Quality app* as the average number of normalized citations per year, and the variable *Acad Quality PI* as the average number of normalized citations per year of the PI, as the team leader.

As a horizontal measure of research orientation, we construct a variable of how applied, relative to how basic, the research of each researcher is. To construct the measure, we use the four categories of the Patent Board classification of journals: (1) applied technology, (2) engineering and technological science, (3) applied and targeted basic research, and (4) basic scientific research. Part of the prior research considers the first two categories applied and the last two basic (Breschi et al., 2008), while other authors consider the first and the third categories applied and the second and the fourth basic (Van Looy et al., 2006). We define the degree of applied orientation of a researcher as the fraction of her publications in the previous five years in the first category relative to the publications in all four categories. This measure allows us to reflect the research orientation on a continuous $[0,1]$ interval scale. We define the variable *Applied Orient app* as the average degree of applied orientation of the application team, and the variable *Applied Orient PI* as the applied orientation of the PI.

We also construct vertical and horizontal personal characteristics of the applicants. We define the dummy variable *Russell Gr app*, which takes the value of 1 if the host institution is (and thus, whether the applicant team members are from) one of the Russell Group universities. We define the variable *Ratio Female app* as the fraction of females in the application team. We also define the dummy variable *Asian app*, which indicates whether at least one of the applicant team members is of Asian origin. Similarly, we create two dummy variables: *Gender PI*, which equals 1 if the PI is a female, and *Asian PI*, which equals 1 if the PI's race is Asian.

Panel member characteristics We construct analogous variables for the panel members as we do for the members of the applicant team. In particular, we create the variables *Acad Quality pan* and *Applied Orient pan* for each panel to measure the research-related vertical and horizontal characteristics of each panel. As personal characteristics, we define the variable *Ratio Female pan* as the percentage of women in the panel and the dummy variable *Asian pan* to identify whether at least one panel member's race is Asian.

We define the variable *Russell Gr pan* in a slightly different way than *Rus-*

sell Gr app, as the median percentage of panel members from the Russell group is above 80% (only ten panels did not include a researcher from the Russell group). Therefore, we define the variable *Russell Gr pan* as a dummy variable that indicates whether the panel has a fraction of members from the Russell group larger than the median fraction of all panels.

Cross variables We include three "cross-variables" between the applicants and panels, i.e., variables that use information from the two sides. The dummy variable *Experience as Panelist* indicates whether at least one member of the applicant team had the experience of being a panel member before the date of application. We also use two variables that capture connections between applicants and panel members. We create the dummy variable *Connection as Colleague*, which measures whether there is an applicant and a panel member who are from the same university, and the dummy variable *Connection as Pre-doc*, which indicates whether there is an applicant who defended the Ph.D. in one of the universities of the panel members.

Control variables We include the size of the applicant team (*Size Team app*) and the square of the size (*Size Team app sq*). That is, we allow for non-linear effects, following the results of the team science literature (for a review, see von Tunzelmann et al., 2003). Similarly, we include the size of the panel (*Size pan*) and the square (*Size pan sq*).

Our regressions also control for the *Duration* of the project and the per-capita amount of funding requested (*Funds per cap*). Moreover, in all the regressions (following Banal-Estañol et al., 2019a), we include the overall fraction of money awarded in that quarter, denoted as *Fraction Awarded*, and constructed as the ratio between the total amount of funds disbursed by our EPSRC panels and the total amount requested.

Types of panels We classify panels using research-related and personal characteristics. We consider a panel "Top," and define the dummy variable *Top pan* if its research quality is in the first quartile of the distribution of the quality of all the panels. Similarly, we consider a panel "Applied," and define the dummy variable *Applied pan*, if the panel's applied orientation, i.e., its level of appliedness, is above the median of all the panels.

At the personal level, we consider a panel "Russell" and "Female," and define the dummy variables *Russell Gr pan* and *Female pan*, if the fraction of members of the Russell group and of females is above the median fraction of all the panels, respectively. As mentioned above, we create the dummy variable *Asian pan* for the panels that include at least one Asian member.

3.2.4 Descriptive statistics

We present descriptive statistics of the main variables in Table 3.2. The percentage of applications that are successfully awarded is almost 30%. The applicants' average normalized citations per year are 7.21, and the average applied orientation is 0.24.[7] Over 79% of applications originate from a university of the Russell group. The average percentage of female researchers in application teams is 6.4% (over 13% of the application teams include at least one female researcher). Around 13.2% of the application teams have at least one Asian researcher.

For panels, the average academic quality and the average applied orientation are 33.7 and 0.2, respectively. By construction, roughly half of the panels have a percentage of Russell group members above the median percentage of all panels (the median is 80%). The average ratio of female members in panels is 11.3% (around 64% of panels include at least one female member). Almost 19% panels include at least one member whose race is Asian.

Finally, in our database, 31.9% teams include at least one academic who has experience being a panel member before the application. More than 23% of the applications are evaluated by a panel that includes at least a member affiliated

[7] As a reference, note that if the publications were homogeneously distributed among the four categories, the average applied orientation would be 0.25.

Table 3.2: **Descriptive statistics**

Dependent variable	Observations	Mean	Std. Dev.	Median
Award	7189	0.299	0.458	0
Team's characteristics	Observations	Mean	Std. Dev.	Median
Acad Quality app	7189	0.721	1.250	0.323
Applied Orient app	7189	0.243	0.312	0.100
Russell Gr app	7189	0.795	0.404	1
Ratio Female app	7189	0.064	0.195	0
Asian app	7189	0.132	0.339	0
Panel's characteristics	Observations	Mean	Std. Dev.	Median
Acad Quality pan	7189	3.370	2.600	2.731
Applied Orient pan	7189	0.200	0.210	0.133
Russell Gr pan	7189	0.461	0.499	0
Ratio Female pan	7189	0.113	0.104	0.111
Asian pan	7189	0.188	0.391	0
Cross variables	Observations	Mean	Std. Dev.	Median
Experience as Panelist	7189	0.319	0.466	0
Connection as Colleague	7189	0.233	0.423	0
Connection as Pre-doc	7189	0.256	0.434	0
Control variables	Observations	Mean	Std. Dev.	Median
Size Team app	7189	2.481	1.570	2
Size pan	7189	9.744	3.307	10
Duration	7189	2.848	0.867	3
Funds per cap	7189	0.136	0.229	0.095
Fraction Awarded	7189	0.314	0.081	0.306
Types of panels	Observations	Mean	Std. Dev.	Median
Top pan	7189	0.253	0.435	0
Applied pan	7189	0.505	0.500	1
Russell Gr pan	7189	0.461	0.499	0
Female pan	7189	0.504	0.500	1
Asian pan	7189	0.188	0.391	0

with the host institution. Similarly, a team member obtained the Ph.D. from the university of a panel member in more than 25% of the applications.

In addition, Table 3.2 shows that the average number of researchers in an application team is 2.5, the average size of a panel is 9.7, and the average duration of a project is 2.8 years. In terms of money, the amount requested per capita for the whole duration of the project is £136,000. The average overall fraction of money awarded within a given quarter is 0.31.

We also present correlations among some of the key variables of the applicants, on one side, and the panelists, on the other, in the top and bottom panels of Table

Table 3.3: **Correlation between the applicant team's and panelists' characteristics**

	Acad Quality app	*Applied Orient app*	*Russell Gr app*	*Ratio Female app*
Applied Orient app	-0.2379***			
Russell Gr app	0.1185***	-0.0043		
Ratio Female app	0.0242**	-0.0436***	-0.0155	
Asian app	0.0143	0.0009	-0.0199*	-0.0073

	Acad Quality pan	*Applied Orient pan*	*Russell Gr pan*	*Ratio Female pan*
Applied Orient pan	-0.3325***			
Russell Gr pan	0.1648***	-0.1184***		
Ratio Female pan	-0.0407***	0.0064	0.0031	
Asian pan	0.0613***	-0.0330***	-0.0171	0.0056

3.3, respectively. Higher quality applicants, and panelists, are also more basic. Albeit significant, these correlations are not very high (the correlations between academic quality and applied orientation are -0.24 and -0.33). Members of the Russell group, both as applicants and panelists, also have higher academic quality. Interestingly, applicant teams with a higher ratio of female participants are also of higher quality and more basic. In the panels, it is the opposite: panels of higher quality involve fewer women.

3.3 Basic determinants of success

This section shows the effects, on the probability that an application is awarded funding, of the research and personal characteristics of the team of applicants, on the one hand, and of the panel members, on the other. We also analyze the effects of the cross-variables. We will use the analysis in this section as a basis of our main analysis, of how particular types of panels treat particular types of applications, described in the following section.

Table 3.4 shows how the likelihood of having a grant awarded depends on the characteristics of the applicants, those of the panel members, the cross variables, and the controls. The coefficients reported correspond to the marginal effects of a probit regression.[8]

Applicant characteristics In terms of research characteristics, row 1 in column 1 shows, as one would expect, that a more accomplished team of applicants, in terms of citations, is more likely to succeed. This is consistent with the results in prior literature (e.g., Grimpe, 2012, and Tamblyn et al., 2018). In terms of magnitude, a one standard deviation increase in applicants' research performance increases the probability of success by 2.1% (1.250*0.017=0.021) or 7.1% of the unconditional probability (0.021/0.299=0.071).

Considering the team's research orientation (row 2), more applied teams are less likely to be successful (as in Tamblyn et al., 2018, and Banal-Estañol et al., 2019a, 2019b). The effect of this (horizontal) characteristic is also significant, although weaker than that of research performance. In terms of magnitude, a one standard deviation increase in applicants' applied orientation decreases the probability of success by 1.1% (0.312*0.036=0.011) or 3.7% of the unconditional probability (0.011/0.299=0.037).

In terms of demographics, the applicants' affiliation to a university (the host institution of the project) that is part of the elite (Russell) group positively affects the probability of success (row 3). In terms of size, it represents 10.7% of the unconditional probability (0.032/0.299=0.107). Note that this effect is additional to that of the quality of their research. This is consistent with the results of Peters and Ceci (1982), who showed that researchers affiliated with prestigious institutions tended to fare better than colleagues at less prestigious ones in the publication process. The universities in the Russell group may also provide better support to their research teams in the application process.[9]

In terms of the personal traits, teams that include more female researchers

[8] Results are similar if we use instead a linear probability model.

[9] O'Kane et al. (2021) highlight the importance of the universities' pre-grant funding support to the researchers in New Zealand's universities.

Table 3.4: **Average effects**

	Initial	*Experience*	*Connections*	*Average effect*	*PI Average effect*	*Panel FE*
	(1)	(2)	(3)	(4)	(5)	(6)
APPLICANTS						
Acad Quality app/PI	0.017***	0.016***	0.017***	0.015***	0.028***	0.021***
	[0.005]	[0.005]	[0.005]	[0.005]	[0.008]	[0.006]
Applied Orient app/PI	-0.036*	-0.035*	-0.036*	-0.036*	-0.024	-0.054**
	[0.019]	[0.019]	[0.019]	[0.019]	[0.018]	[0.021]
Russell Gr app	0.032**	0.031**	0.031**	0.030**	0.026*	0.044***
	[0.013]	[0.013]	[0.014]	[0.014]	[0.014]	[0.015]
Ratio Female app/Gender PI	-0.040	-0.046*	-0.040	-0.046*	-0.047**	-0.024
	[0.027]	[0.028]	[0.027]	[0.028]	[0.022]	[0.031]
Asian app/Asian PI	-0.043***	-0.040**	-0.043***	-0.040**	-0.065***	-0.030*
	[0.016]	[0.016]	[0.016]	[0.016]	[0.023]	[0.018]
PANELS						
Acad Quality pan	-0.010***	-0.010***	-0.010***	-0.010***	-0.009***	
	[0.003]	[0.003]	[0.003]	[0.003]	[0.003]	
Applied Orient pan	0.007	0.007	0.007	0.007	0.015	
	[0.028]	[0.028]	[0.028]	[0.028]	[0.030]	
Russell Gr pan	0.008	0.007	0.008	0.007	0.002	
	[0.011]	[0.011]	[0.011]	[0.011]	[0.011]	
Ratio Female pan	-0.166***	-0.162***	-0.166***	-0.161***	-0.173***	
	[0.052]	[0.052]	[0.052]	[0.052]	[0.054]	
Asian pan	-0.030**	-0.030**	-0.030**	-0.030**	-0.029**	
	[0.014]	[0.014]	[0.014]	[0.014]	[0.015]	
CROSS VARIABLES						
Experience as Panelist		0.038***		0.038***	0.044***	0.069***
		[0.012]		[0.012]	[0.014]	[0.014]
Connection as Colleague			0.008	0.008	0.007	0.004
			[0.013]	[0.013]	[0.014]	[0.015]
Connection as Pre-doc			0.004	0.003	0.003	0.003
			[0.013]	[0.013]	[0.014]	[0.015]
CONTROLS						
Size Team app	-0.045***	-0.049***	-0.045***	-0.049***	-0.042***	-0.036***
	[0.011]	[0.011]	[0.011]	[0.011]	[0.011]	[0.012]
Size Team app sq	0.004***	0.004***	0.004***	0.004***	0.004***	0.003*
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.002]
Size pan	-0.006	-0.006	-0.006	-0.006	-0.004	
	[0.005]	[0.005]	[0.005]	[0.005]	[0.005]	
Size pan sq	-0.000	-0.000	-0.000	-0.000	-0.000	
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	
Duration	0.032***	0.032***	0.031***	0.031***	0.032***	0.041***
	[0.008]	[0.008]	[0.008]	[0.008]	[0.008]	[0.010]
Funds per cap	-0.311***	-0.312***	-0.311***	-0.311***	-0.318***	0.009
	[0.062]	[0.062]	[0.062]	[0.062]	[0.065]	[0.034]
Fraction Awarded	0.457***	0.455***	0.457***	0.454***	0.447***	0.110
	[0.081]	[0.081]	[0.081]	[0.081]	[0.085]	[0.091]
Year fixed effects	Yes	Yes	Yes	Yes	Yes	-
Panel fixed effects	-	-	-	-	-	Yes
Observations	7,189	7,189	7,189	7,189	6,637	6,116

Notes. This table reports marginal effects from probit regressions for the likelihood that a project is awarded. The dependent variable *Award* is a dummy equal to 1 if the project is awarded and 0 otherwise. Independent variables are characteristics of the team of applicants and the evaluation panel, and controls. All variables are defined in Table 3.1. Column (2) includes *Experience as Panelist*, which is a dummy equal to 1 if an applicant has experience as member of panels and 0 otherwise. Column (3) includes the variables *Connection as Colleague* and *Connection as Pre-doc*, which are dummies equal to 1 if some applicant has the same affiliation or has defended the Ph.D., respectively, at the same department as some panel member and 0 otherwise. Column (4) includes all the previous variables. Column (5) replicates column (4) using the variables corresponding to the PI instead of the team. In these regressions, we include year fixed effects. Column (6) replicates column (4) without the panel variables and with panel fixed effects. Robust standard errors are reported in parentheses.

$***$, $**$, and $*$ indicate significance at the 1%, 5%, and 10% level, respectively.

(row 4) or academics of an Asian origin (row 5) are less likely to succeed in the grant application process. However, the first effect is not significant in the first regression. These results are also consistent with those of previous literature on the effects of gender and race in the grant application process (e.g., Viner et al., 2004, and Wold and Wennerås, 1997).

Panel member characteristics Turning to the characteristics of the panel members evaluating a particular grant, being assessed by a more accomplished panel, again in terms of citations, decreases the chances that the application is awarded (row 6). This result suggests, interestingly but perhaps unsurprisingly, that higher academic quality panels are more demanding. In terms of magnitude, a one standard deviation increase in the panel's research performance decreases the probability of success by 2.6% (2.600*0.010=0.026) or 8.6% of the unconditional probability (0.026/0.299=0.086). This effect, in absolute value, is stronger than the one of the applicants.

In contrast, the average applied orientation of the panel and whether they have relatively more members affiliated to a Russell group university do not affect the likelihood of success (rows 7 and 8). Panels that include more female members and those that include members of an Asian origin are also less likely to award the grant (rows 9 and 10). Our results on gender are consistent with those of the few papers that analyse the effects of panel characteristics on grant success (Jayasinghe et al., 2003, and Tamblyn et al., 2018). We do not know of previous research that has studied the effects of the other characteristics.

Cross variables Column 2 highlights that teams of applicants with at least one researcher with experience as a panel member have higher chances of success, conditional on the rest of the characteristics of the applicants and panel members. We also analyse the effects of the links between the applicants and the panel. Column 3 shows that they are not significant: the likelihood of success does not change if the affiliation of a panel member coincides with that of a team member or with the university where s/he earned the Ph.D. Column 4 confirms the results of the previous columns when we include all the cross-applicant-panel variables together.

Our results on experience are in line with those of Viner et al. (2004) who, using data also from the EPSRC, associate success in securing grants with experience in the peer review system. But our connection results stand in contrast with those of Wold and Wennerås (1997), as well as Sandström and Hällsten (2008), who show that applicants sharing an institutional affiliation with the panels were more likely to be successful in the award decisions of the Swedish Medical Research Council. Thus, our results suggest that the EPSRC deals with conflicts of interest in an adequate way.

Control variables In terms of controls, the number of applicants has a non-linear, U-shaped effect on success. The project's duration has a positive impact, whereas the amount requested per person harms the chances of success. This is consistent with previous results (Banal-Estañol et al., 2019a). The size of the panel does not affect the likelihood of success in any way. Naturally, we find that applications in periods where grants are more likely to be awarded have a higher chance of success.

Robustness We will use column 4 as a basis for the analysis of the next section. It highlights, in particular, the average effects of the panel characteristics on the applicants' likelihood of success. Column 5 shows that the previous average effects results are maintained if we use the characteristics of the PI rather than those of the whole team of applicants. The only difference is that the degree of appliedness does not longer significantly affect the chances of success, whereas being a female PI harms the likelihood of success, now, significantly. We also note that the PI's academic quality has a stronger influence than that of the whole team.

Finally, column 6 shows that the results for the characteristics of the applicant teams and the cross-applicant-panel variables are similar when we include panel fixed effects. Analysing the overall impact of the panel characteristics is one of our main objectives. For this reason, we will not include panel fixed effects in the following section. We prefer keeping the variables that reflect the characteristics of the panel. Untabulated regressions show that all the results present in the following tables hold if we use panel fixed effects instead of the panels' variables.

3.4 Similar-to-me effects

The previous section shows that not only the characteristics of the applicants but also the characteristics of the panels influence the award decisions. Some panels are tougher than others. This section goes a step forward. We investigate how the effects of the characteristics of the applicants vary with the characteristics of the panel evaluating the application. We put particular emphasis on understanding whether panel members favor (or penalise less) those academics with characteristics similar to theirs, as the "similar-to-me" hypothesis suggests.

We follow two empirical strategies. First, we run split sample regressions based on the panels' research-related and personal characteristics (top vs. non-top, applied vs. non-applied or basic, Russell vs. non-Russell, female vs. non-female, and Asian vs. non-Asian). We compare the coefficients of these regressions with those of the (average effects) regression of the previous section (column 4 of Table 3.4). As in the previous section, the coefficients correspond to the marginal effects of the probit regressions. Second, we define dummy variables using the same panel classifications and run and interpret interaction effects regressions, interacting these panel variables first with all the applicant variables and then with the corresponding applicant variable. We report, in this case, the coefficients rather than the marginal effects, as there are no marginal effects for the interaction terms. All regressions include all the variables of the previous section, although the coefficients of the controls are not displayed.

3.4.1 Top vs. non-top panels

Table 3.5 distinguishes panels by research performance of their members, proxied by the average number of citations of their members (top quartile vs. bottom three quartiles of the distribution of panels). As a reference, we keep the results of the "average effect" regression of the previous section, reporting its marginal effects in column 1 (i.e., the same as column 4 of Table 3.4) and the coefficients in column 4.

Columns 2 and 3 show that the research quality of the applicants is more important and more significant for panels of the highest quality than for those of relatively lower quality. In terms of magnitudes, a one standard deviation increase in the applicants' research performance increases the probability of success by 3.3% (1.250*0.026=0.033) or 11.0% of the unconditional probability if evaluated by a top panel (0.033/0.299=0.110) whereas it is increased by just 1.3% or 4.3% of the unconditional probability of success if evaluated by a non-top panel. The empirical p-value in Fisher's permutation test is 0.062, which suggests that the difference in the coefficients of the two groups is statistically significant.[10] Thus, top panels are not only more demanding, in general, but they care more about the applicant team's research performance than the other panels. In terms of magnitudes, a one standard deviation increase in the applicants' research performance increases the probability of success by an additional 6.7% of the unconditional probability if it is evaluated by a top rather than by a non-top panel. These regressions also suggest that the reference (average) effects of the quality of the applicants, discussed in the previous section, and displayed again in Column 1, are mainly driven by the top quality panels.

Columns 5 and 6 show that the results are similar when using an interaction approach rather than a split-sample approach. They present the coefficients of the regressions when we include, in addition to the variables in Column 4, the interaction of the applicant's variables with the dummy "Top pan," which indicates

[10] Fisher's permutation test is used to test whether there is a significant difference between the coefficients in different groups. For more details see, for instance, Soms (1977).

Table 3.5: **Research quality of the panel members**

	Average effect	*Top pan*	*non-Top pan*	*Average effect*	*Interaction all*	*Interaction Quality*
	(1)	(2)	(3)	(4)	(5)	(6)
APPLICANTS						
Acad Quality app	0.015***	0.026***	0.010*	0.046***	0.026	0.025
	[0.005]	[0.008]	[0.006]	[0.014]	[0.016]	[0.016]
Applied Orient app	-0.036*	-0.068	-0.040*	-0.106*	-0.093	-0.101*
	[0.019]	[0.046]	[0.021]	[0.055]	[0.060]	[0.055]
Russell Gr app	0.030**	0.020	0.033**	0.088**	0.092**	0.090**
	[0.014]	[0.028]	[0.015]	[0.040]	[0.045]	[0.040]
Ratio Female app	-0.046*	-0.033	-0.042	-0.136*	-0.135	-0.140*
	[0.028]	[0.047]	[0.034]	[0.082]	[0.099]	[0.082]
Asian app	-0.040**	-0.036	-0.043**	-0.120**	-0.124**	-0.120**
	[0.016]	[0.031]	[0.019]	[0.048]	[0.055]	[0.048]
INTERACTIONS						
Top pan×Acad Quality app					0.052*	0.054*
					[0.029]	[0.028]
Top pan×Applied Orient app					-0.051	
					[0.150]	
Top pan×Russell Gr app					-0.008	
					[0.097]	
Top pan×Ratio Female app					-0.020	
					[0.176]	
Top pan×Asian app					0.018	
					[0.111]	
PANELS						
Acad Quality pan	-0.010***	-0.007	-0.028***	-0.029***		
	[0.003]	[0.005]	[0.007]	[0.008]		
Applied Orient pan	0.007	0.073	-0.016	0.022	0.064	0.064
	[0.028]	[0.086]	[0.031]	[0.084]	[0.082]	[0.082]
Russell Gr pan	0.007	0.014	0.001	0.022	0.016	0.016
	[0.011]	[0.023]	[0.013]	[0.033]	[0.033]	[0.033]
Ratio Female pan	-0.161***	-0.134	-0.173***	-0.480***	-0.454***	-0.455***
	[0.052]	[0.109]	[0.060]	[0.155]	[0.156]	[0.156]
Asian pan	-0.030**	-0.050*	-0.009	-0.090**	-0.082*	-0.083**
	[0.014]	[0.029]	[0.017]	[0.042]	[0.042]	[0.042]
Top pan					-0.107	-0.123**
					[0.097]	[0.048]
CROSS VARIABLES						
Experience as Panelist	0.038***	0.040*	0.038***	0.113***	0.113***	0.113***
	[0.012]	[0.023]	[0.015]	[0.037]	[0.037]	[0.037]
Connection as Colleague	0.008	0.004	0.011	0.025	0.023	0.023
	[0.013]	[0.024]	[0.016]	[0.040]	[0.040]	[0.040]
Connection as Pre-doc	0.003	0.016	-0.005	0.008	0.008	0.008
	[0.013]	[0.024]	[0.016]	[0.039]	[0.039]	[0.039]
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,189	1,820	5,369	7,189	7,189	7,189

Notes. This table presents the results of probit regressions for the likelihood that a project is awarded. The dependent variable *Award* is a dummy equal to 1 if the project is awarded and 0 otherwise. Independent variables are characteristics of the team of applicants, characteristics of the evaluation panel, and some controls. All variables are defined in Table 3.1. Columns (2) and (3) replicate column (1) for the subset of projects evaluated for panels in the first quartile and in the other quartiles, respectively, in terms of average number of citations of the panels. Columns (1) to (3) report marginal effects. Column (4) reports the coefficients from the same regression as column (1). Column (5) includes the interaction of the five applicants' characteristics with a dummy equal to 1 if the panel is in the first quartile in terms of average citations and 0 otherwise. Column (6) only includes the interaction with the quality of the applicants. In all regressions, we include year fixed effects. Robust standard errors are reported in parentheses.
$***$, $**$, and $*$ indicate significance at the 1%, 5%, and 10% level, respectively.

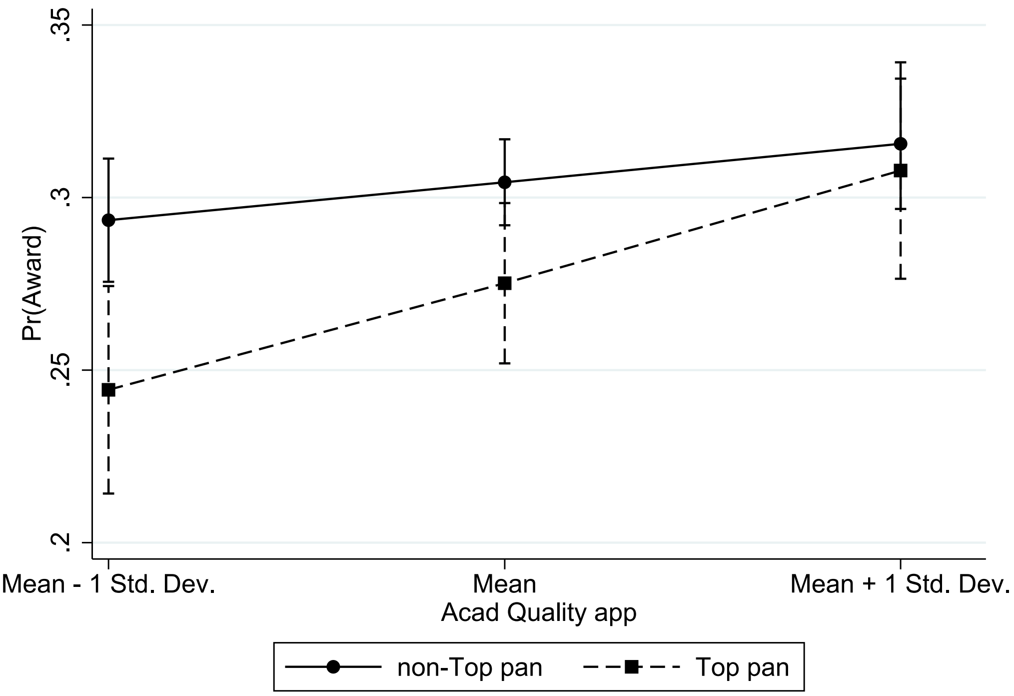
whether the panel is in the top quartile of quality. Column 5 shows that the main effect of the applicant citations, i.e., the impact for the bottom three panels, is non-significant. Instead, the interaction term is positive and significant, indicating that the quality of the applicants is significantly more important for the panels of the highest quality. Column 6 confirms that the result is the same if, instead of interacting the top panel variable with all the applicant variables, we only interact it with their quality.

Figure 3.1 provides a graphical representation of the results of Column 5. We depict the estimated probability of success for a team of an average research performance, as well as for those at one standard deviation above and below that average. As explained before, the probability of success of an average team, in terms of research performance, is lower if evaluated by a top panel rather than by a non-top panel. But an increase in the applicants' research performance increases the probability of success by more if they are evaluated by a top rather than by a non-top panel, i.e., the slope is steeper. Still, for all the range depicted, the probability of success of an applicant team is always lower if evaluated by a top panel.

These results show that the similar-to-me hypothesis is satisfied along the research performance dimension in the grant selection process. Following the social psychology theory, high-performers may consider themselves a social category. The desire to have a positive self-identity makes high-performing panel members reward high-performing applicants more strongly (Turner et al., 1987). Although research-related characteristics may not be considered standard social categories, high-performing individuals may see themselves as a self category that differentiates them from low-performing individuals. Similarly, high-performing individuals may consider other high-performing individuals attractive, as they are perceived to be similar in attitudes and values. This association might also affect evaluation decisions (Byrne, 1971).

Our setting also allows us to identify cross-effects, along different dimensions, between types of panels and characteristics of the applicants. As shown in columns 2 and 3, the positive effect of the affiliation to a Russell group university, identified

Figure 3.1: **Marginal effects of academic quality of interaction term**



Notes. The solid (dashed) line represents the likelihood of obtaining a grant for a team whose academic quality is one standard deviation below the mean, the mean, and one standard deviation above the mean, when evaluated by non-top (top) panels with 95% confidence intervals. The dashed line is below the solid line, but it is steeper, showing that top panels are more demanding than non-top panels, and they care more about the applicant team's research performance.

in the previous section, is significant for the bottom panels but not for the top panel. As shown in Column 5, the main effect of the Russell group (i.e., for the bottom panels) is significant, whereas the interaction effect (difference of the top panel relative to the others) point to the other direction, albeit it is not significant. These results suggest that lower-quality panels may provide more importance to coarser measures of quality such as institutional affiliation rather than actual research quality.

Columns 2 and 3 of Table 3.6 illustrate that the results are similar if we use the PI to construct the applicant measures instead of using the whole team. They show again that the quality of research of the applicant is more important for panels of the highest quality than for those of relatively lower quality (the p-value of the difference in Fisher's permutation test is 0.089). Thus, the reference (average) effects of the quality of the applicant, and displayed again in Column 1, are mainly driven by the panels of top quality.

Table 3.6: **Research related measures of the panel members and PI characteristics**

	PI Average effect	*Top pan*	*non-Top pan*	*Applied pan*	*non-Applied pan*
	(1)	(2)	(3)	(4)	(5)
PRINCIPAL INVESTIGATORS					
Acad Quality PI	0.028***	0.045***	0.021**	0.007	0.034***
	[0.008]	[0.014]	[0.010]	[0.017]	[0.010]
Applied Orient PI	-0.024	-0.048	-0.028	-0.012	-0.061*
	[0.018]	[0.044]	[0.020]	[0.023]	[0.032]
Russell Gr app	0.026*	0.016	0.029*	0.044**	0.007
	[0.014]	[0.030]	[0.016]	[0.020]	[0.021]
Gender PI	-0.047**	-0.061	-0.035	-0.053	-0.041
	[0.022]	[0.040]	[0.026]	[0.033]	[0.029]
Asian PI	-0.065***	-0.062	-0.067**	-0.061**	-0.064*
	[0.023]	[0.045]	[0.027]	[0.031]	[0.033]
PANELS					
Acad Quality pan	-0.009***	-0.007	-0.024***	-0.000	-0.015***
	[0.003]	[0.005]	[0.007]	[0.005]	[0.004]
Applied Orient pan	0.015	0.083	-0.005	-0.004	0.246
	[0.030]	[0.089]	[0.032]	[0.045]	[0.190]
Russell Gr pan	0.002	0.014	-0.004	0.023	-0.011
	[0.011]	[0.024]	[0.013]	[0.016]	[0.016]
Ratio Female pan	-0.173***	-0.108	-0.188***	-0.112	-0.259***
	[0.054]	[0.114]	[0.063]	[0.078]	[0.077]
Asian pan	-0.029**	-0.051*	-0.008	-0.008	-0.053**
	[0.015]	[0.030]	[0.017]	[0.021]	[0.021]
CROSS VARIABLES					
Experience as panelist	0.044***	0.049*	0.043***	0.049**	0.043**
	[0.014]	[0.025]	[0.017]	[0.021]	[0.019]
Connection as Colleague	0.007	-0.008	0.015	0.015	-0.002
	[0.014]	[0.025]	[0.017]	[0.021]	[0.019]
Connection as Pre-doc	0.003	0.021	-0.007	0.024	-0.018
	[0.014]	[0.025]	[0.016]	[0.020]	[0.019]
Control variables	Yes	Yes	Yes	Yes	Yes
Year Fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	6,637	1,701	4,936	3,325	3,312

Notes. This table reports marginal effects from probit regressions for the likelihood that a project is awarded. The dependent variable *Award* is a dummy equal to 1 if the project is awarded and 0 otherwise. Independent variables are characteristics of the PI and the evaluation panel, cross variables, and controls. All variables are defined in Table 3.1. Columns (2) and (3) replicate column (1) for the subset of projects evaluated for panels in the first quartile and in the other quartiles, respectively, in terms of average number of citations of the panels. Columns (4) and (5) replicate column (1) for the subset of projects evaluated for panels above and below the median, respectively, in terms of appliedness of the panel members. In all regressions, we include year fixed effects. Robust standard errors are reported in parentheses.
$***$, $**$, and $*$ indicate significance at the 1%, 5%, and 10% level, respectively.

Finally, unreported regressions show that the differences between the top quartile and the bottom three quartiles are stronger than those of the top and bottom two (or above and below the median), both when using the characteristics of the PI or the whole applicant team. This means that the differences, in terms of quality, are relevant at the top of the distribution of the panel.

Table 3.7: **Applied orientation of the panel**

	Average effect	*Applied pan*	*non-Applied pan*	*Average effect*	*Interaction all*	*Interaction Orient*
	(1)	(2)	(3)	(4)	(5)	(6)
APPLICANTS						
Acad Quality app	0.015***	0.020**	0.016***	0.046***	0.034**	0.045***
	[0.005]	[0.010]	[0.005]	[0.014]	[0.015]	[0.014]
Applied Orient app	-0.036*	-0.011	-0.083**	-0.106*	-0.247**	-0.233**
	[0.019]	[0.023]	[0.033]	[0.055]	[0.099]	[0.099]
Russell Gr app	0.030**	0.051***	0.004	0.088**	0.003	0.088**
	[0.014]	[0.019]	[0.020]	[0.040]	[0.059]	[0.040]
Ratio Female app	-0.046*	-0.073*	-0.024	-0.136*	-0.071	-0.132
	[0.028]	[0.042]	[0.036]	[0.082]	[0.109]	[0.082]
Asian app	-0.040**	-0.036	-0.045**	-0.120**	-0.158**	-0.120**
	[0.016]	[0.022]	[0.023]	[0.048]	[0.069]	[0.048]
INTERACTIONS						
Applied pan×Acad Quality app					0.055*	
					[0.032]	
Applied pan×Applied Orient app					0.213*	0.175
					[0.119]	[0.117]
Applied pan×Russell Gr app					0.155*	
					[0.080]	
Applied pan×Ratio Female app					-0.138	
					[0.165]	
Applied pan×Asian app					0.077	
					[0.095]	
PANELS						
Acad Quality pan	-0.010***	-0.003	-0.015***	-0.029***	-0.029***	-0.028***
	[0.003]	[0.005]	[0.004]	[0.008]	[0.008]	[0.008]
Applied Orient pan	0.007	0.003	0.197	0.022		
	[0.028]	[0.042]	[0.182]	[0.084]		
Russell Gr pan	0.007	0.026*	-0.006	0.022	0.024	0.023
	[0.011]	[0.016]	[0.016]	[0.033]	[0.033]	[0.033]
Ratio Female pan	-0.161***	-0.119	-0.222***	-0.480***	-0.486***	-0.468***
	[0.052]	[0.074]	[0.074]	[0.155]	[0.156]	[0.155]
Asian pan	-0.030**	-0.014	-0.051**	-0.090**	-0.091**	-0.090**
	[0.014]	[0.020]	[0.020]	[0.042]	[0.042]	[0.042]
Applied pan					-0.182**	-0.012
					[0.080]	[0.042]
CROSS VARIABLES						
Experience as Panelist	0.038***	0.043**	0.031*	0.113***	0.109***	0.113***
	[0.012]	[0.018]	[0.017]	[0.037]	[0.037]	[0.037]
Connection as Colleague	0.008	0.007	0.005	0.025	0.025	0.024
	[0.013]	[0.020]	[0.019]	[0.040]	[0.040]	[0.040]
Connection as Pre-doc	0.003	0.027	-0.021	0.008	0.008	0.009
	[0.013]	[0.019]	[0.018]	[0.039]	[0.039]	[0.039]
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,189	3,631	3,558	7,189	7,189	7,189

Notes. This table presents the results of probit regressions for the likelihood that a project is awarded. The dependent variable *Award* is a dummy equal to 1 if the project is awarded and 0 otherwise. Independent variables are characteristics of the team of applicants and the evaluation panel, cross variables, and controls. All variables are defined in Table 3.1. Columns (2) and (3) replicate column (1) for the subset of projects evaluated for panels above and below the median, respectively, in terms appliedness of the panel members. Columns (1) to (3) report marginal effects. Column (4) reports the coefficients from the same regression as column (1). Column (5) includes the interaction of the five applicants' characteristics with a dummy equal to 1 if the panel is above median in terms of appliedness and 0 otherwise. Column (6) only includes the interaction with the applied orientation of the applicants. In all regressions, we include year fixed effects. Robust standard errors are reported in parentheses.
$***$, $**$, and $*$ indicate significance at the 1%, 5%, and 10% level, respectively.

3.4.2 Applied vs. basic panels

Table 3.7 distinguishes between "applied" and "non-applied" or basic panels, defined as those above and below, respectively, of the median level of average appliedness of the panels.[11] As a reference, we keep again the results of the "average effect" regression of the previous section, reporting its marginal effects in column 1 (i.e., the same as column 4 of Table 3.4) and the coefficients in column 4.

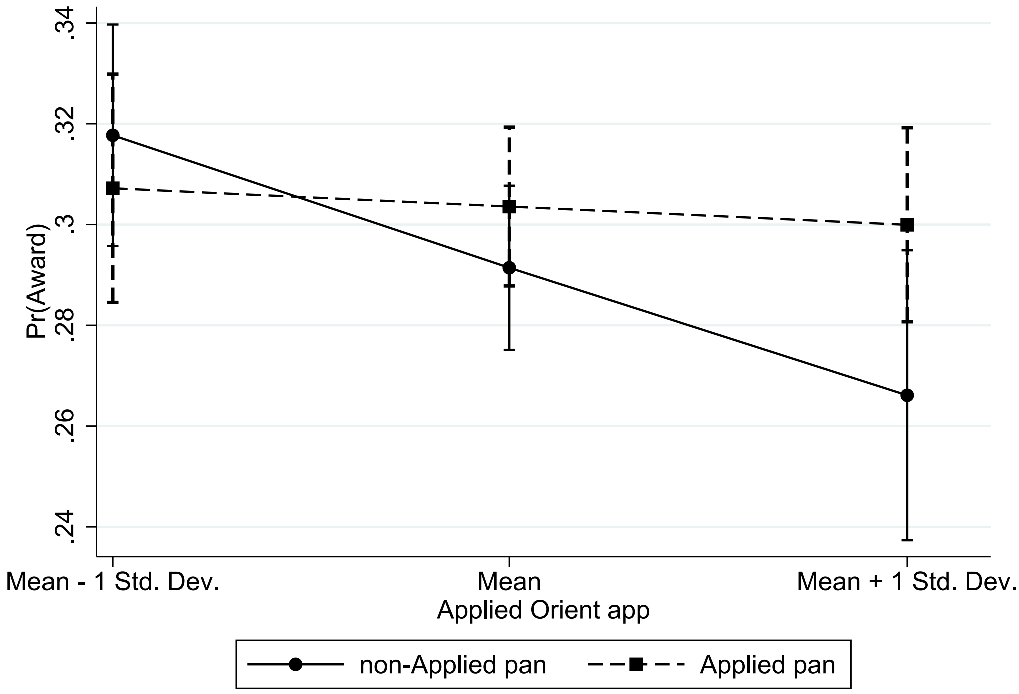
Columns 2 and 3 show that the degree of appliedness of the team of applicants decreases the chances of success only if a non-applied panel evaluates them. In terms of magnitudes, a one standard deviation increase in the applicants' applied orientation decreases the probability of success by 2.6% (0.312*0.083=0.026) or 8.7% of the unconditional probability if evaluated by a basic panel (0.025/0.299=0.087) whereas it is decreased by just 0.3% or 1.0% of the unconditional probability of success if evaluated by an applied panel. The empirical p-value of the difference between the coefficients of the two groups is significant, 0.018 according to Fisher's permutation test. Thus, the reference (average) effects of the type of research of the applicants, discussed in Section 3.3, and displayed again in Column 1, are driven by the non-applied panels only.

Columns 5 and 6 corroborate this result using an interaction approach rather than a split-sample approach. Figure 3.2 provides a graphical representation of the results of Column 5. We depict the estimated probability of success for a team of an average research orientation, as well as for those at one standard deviation above and below this average. As shown before, the probability of success for a team of an average orientation is slightly larger for applied than for basic panels, but the difference is statistically insignificant. But an increase in the applicants' applied research orientation decreases the probability of success by more if they are evaluated by a basic rather than by an applied panel, i.e., the slope is steeper (downwards). In that level of the applicants' research orientation, the difference between basic

[11] We note that more basic panel members have more citations, that is, there is a negative correlation between panels' citations and appliedness. The correlation between the dummies that we use in the previous and the current subsections is -0.2463 and significant.

and applied panels is significant. If, instead of increasing, we decrease the research orientation by one standard deviation, there is a crossing in the estimated probabilities of success, and the basic panels become more benevolent than the applied panels, but the difference is still insignificant.

Figure 3.2: **Marginal effects of applied orientation for interaction term**



Notes. The solid (dashed) line represents the likelihood of obtaining a grant for a team whose applied orientation is one standard deviation below the mean, the mean, and one standard deviation above the mean, when evaluated by non-applied (applied) panels with 95% confidence intervals. The non-applied panel's line is steeper, showing that an increase in the research orientation (i.e., a more applied team) reduces a team's probability of success more when non-applied panels evaluate them than when applied panels do.

Moreover, columns 4 and 5 of Table 3.6 show that an applied PI is less likely to get funded than a basic PI, but only if the research orientation of the evaluating panel is not applied. The difference between the coefficients of the variable *Applied Orient PI* is significant since the empirical p-value of the difference according to Fisher's permutation test is 0.086.

These results confirm that the similar-to-me hypothesis is also satisfied along the research orientation dimension. As in the case of research performance, basic researchers may consider themselves a social category. The desire to have a positive self-identity leads basic panel members to penalise applied applicants. Similarly, basic individuals may consider applied individuals less attractive. This result is akin to the result of Hamermesh and Schmidt (2003), who examine the election of Fellows of the Econometric Society based, among others, on the research area. They show that the area of specialization does affect the probability of election. As theorists are more likely to be elected than econometricians, the authors hypothesize that a potential explanation is that theorists constitute a large fraction of the electorate and are more likely to vote for candidates like themselves.

We can also identify cross-effects, along different dimensions, between types of panels and characteristics of the applicants. Columns 2 and 3 show that the positive effect of the affiliation to a Russell group university and the lower likelihood of success for female applicants are significant for the applied panels only. In contrast, the negative impact of being of an Asian origin is significant for the basic panels only.

3.4.3 Personal characteristics of the panels

Table 3.8 distinguishes between "Russell" and "non-Russell" and "female" and "non-female" panels, based on the comparison of the ratio of Russell group and female members, respectively, and the median of all panels. It also distinguishes between "Asian" and "non-Asian" panels, based on the inclusion of at least one panel member of an Asian origin. As a reference, we keep again the results of the average effects regression of Column 4 of Table 3.4 as column 1.

Columns 2 and 3 show that Russell panels do not favour teams of a Russell group university more than non-Russell panels do. In fact, the coefficient for non-Russell panels is slightly larger (and slightly significant). The difference between the coefficients is not significant, though (the p-value of the difference of coefficients is 0.41). This is the only dimension in which the similar-to-me hypothesis is not fully supported in our analysis. In this sense, the elite/non-elite Russell group categorization we use may be less clear for the academic researchers, than the other

Table 3.8: **Personal characteristics of the panel**

	Average effect	*Russell Gr pan*	*non-Russell Gr pan*	*Female pan*	*non-Female pan*	*Asian pan*	*non-Asian pan*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
APPLICANTS							
Acad Quality app	0.015***	0.011*	0.021***	0.020***	0.011*	0.025**	0.014***
	[0.005]	[0.006]	[0.007]	[0.007]	[0.006]	[0.012]	[0.005]
Applied Orient app	-0.036*	-0.029	-0.050**	-0.025	-0.050*	0.002	-0.045**
	[0.019]	[0.028]	[0.025]	[0.025]	[0.027]	[0.044]	[0.021]
Russell Gr app	0.030**	0.030	0.034*	0.024	0.032	0.015	0.033**
	[0.014]	[0.021]	[0.018]	[0.019]	[0.019]	[0.030]	[0.015]
Ratio Female app	-0.046*	-0.051	-0.034	-0.015	-0.091**	-0.090	-0.039
	[0.028]	[0.041]	[0.037]	[0.036]	[0.042]	[0.065]	[0.030]
Asian app	-0.040**	-0.050**	-0.033	-0.018	-0.058**	-0.028	-0.044**
	[0.016]	[0.024]	[0.021]	[0.022]	[0.023]	[0.032]	[0.019]
PANELS							
Acad Quality pan	-0.010***	-0.009**	-0.008*	-0.002	-0.015***	-0.020***	-0.008***
	[0.003]	[0.004]	[0.004]	[0.004]	[0.004]	[0.007]	[0.003]
Applied Orient pan	0.007	0.051	0.002	0.049	-0.022	0.043	-0.001
	[0.028]	[0.044]	[0.037]	[0.040]	[0.040]	[0.073]	[0.031]
Russell Gr pan	0.007			-0.002	0.014	0.039	-0.001
	[0.011]			[0.016]	[0.016]	[0.025]	[0.012]
Ratio Female pan	-0.161***	-0.265***	-0.064	-0.210**	-0.463**	-0.172	-0.166***
	[0.052]	[0.071]	[0.077]	[0.099]	[0.199]	[0.134]	[0.057]
Asian pan	-0.030**	-0.002	-0.055***	-0.030	-0.033		
	[0.014]	[0.021]	[0.019]	[0.019]	[0.021]		
CROSS VARIABLES							
Experience as Panelist	0.038***	0.046***	0.033**	-0.001	0.076***	0.010	0.045***
	[0.012]	[0.018]	[0.017]	[0.017]	[0.017]	[0.026]	[0.014]
Connection as Colleague	0.008	0.006	0.005	0.001	0.011	0.068**	-0.007
	[0.013]	[0.020]	[0.018]	[0.019]	[0.019]	[0.028]	[0.015]
Connection as Pre-doc	0.003	-0.009	0.010	0.002	-0.000	-0.027	0.011
	[0.013]	[0.019]	[0.018]	[0.019]	[0.019]	[0.029]	[0.015]
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,189	3,314	3,875	3,626	3,563	1,352	5,837

Notes. This table reports marginal effects from probit regressions for the likelihood that a project is awarded. The dependent variable *Award* is a dummy equal to 1 if the project is awarded and 0 otherwise. Independent variables are characteristics of the team of applicants and the evaluation panel, cross variables, and controls. All variables are defined in Table 3.1. Columns (2) and (3) replicate column (1) for the subset of projects evaluated for panels above and below the median, respectively, in terms rate of female among the panel members. Columns (4) and (5) replicate column (1) for the subset of projects evaluated for panels with and without, respectively, panel members of Asian origin. Columns (6) and (7) replicate column (1) for the subset of projects evaluated for panels above and below the median, respectively, in terms rate of members of the panel affiliated to a university in the Russell group. In all regressions, we include year fixed effects. Robust standard errors are reported in parentheses.
$***$, $**$, and $*$ indicate significance at the 1%, 5%, and 10% level, respectively.

categorizations we use in the paper. More than half of the universities in our sample (23/39), and almost 80% of the applications, belong to the so-called Russell group. This result is also consistent with the non-significance of the coefficients of the university connections between the applicants and the panel members that we reported in columns 2-4 of Table 3.4. Taking together, these results suggest that, in the grant allocation process, university affiliation may not lead to a strong self-categorization.

Columns 4 and 5 show that non-female panelists tend to penalise female applicants, whereas female panels do not (the p-value of the difference of the coefficients is 0.085). This is again consistent with the similar-to-me hypothesis. It is, in fact, one of the main dimensions on which the social psychology theories focus. Gender, and in particular being female in such a male-dominated discipline as engineering and the physical sciences, may be an essential social category on which female researchers desire to have a positive self-identity.

Finally, columns 6 and 7 show that non-Asian panels tend to discriminate against Asian applicants more than Asian panels do. However, the difference of the coefficient is not significant according to Fisher's permutation test (the p-value of the difference of coefficients is 0.36). Race is again one of the main dimensions on which the social psychology theory has focused. Failure to achieve significance may be due to the small number of researchers of an Asian origin.

We can also identify cross-effects, along different dimensions, between types of panels and characteristics of the applicants. Female panels, for instance, care mainly about the quality of the team, whereas the non-female panels, as the average results, also take into account the applied orientation, the affiliation to a Russell group university, and the Asian origin.

Let us stress that untabulated regressions confirm the previous results when we use variables that reflect the PI's personal characteristics instead of the team's. First, the likelihood that a PI from the Russell group obtains a grant is similar whether the panel has more members from the Russell group or not. Second, female PIs find it more difficult to get a grant only when non-female panels evaluate them. Finally, the likelihood that a PI is awarded a grant is lower when s/he is of Asian origin only when the evaluating panel has no member of Asian origin. As it happens when we consider the team characteristics, the difference of the coefficients for the characteristics of the PIs is significant for *Gender PI* (the p-value is 0.055), but it is not significant for *Asian PI* (the p-value is 0.236).

3.5 Conclusion

Most research financing programmes rely on panel evaluation systems to select the most promising and meritorious applications. In this process, the panel composition is not neutral. Even if the panel's composition is adequate in terms of knowledge and expertise, its decision may be influenced by its members' views and preferences. In this paper, we have investigated how the characteristics of the panels affect the chances of obtaining funding by different types of applicants. Our main question is whether the similarity, that is, the resemblance between the applicants and the panel, affects the chances that a project is funded.

We have shown that the likelihood that an application obtains funding depends not only on the applicants' traits but also on the composition of the evaluating panel. In particular, high-performing panels, female panelists, and panelists of Asian origin are tougher. More importantly, panelists with a very strong publication record give more weight to the applicants' publication history (and less to other characteristics) than panelists with a weaker record. Also, an application is more likely to be successful if the applicants and the team members are "similar" in terms of research orientation as well as in gender and (Asian) origin. We find thus that there are "similar-to-me" effects in the grant selection process, whereby applicants will be rated more favorably the more similar they are to the rater.

Our analysis suggests that some types of panels are biased since a team's odds of being funded are different depending on the panel's characteristics.[12] Indeed, take for instance research orientation. Provided that it is a horizontal characteristic, it should not influence the likelihood of obtaining funding. In this case, our results suggest that applied panels are not biased, whereas basic panels are. In contrast, if research orientation is not a horizontal characteristic and applied teams have a lower productivity ex-post, then applied panels are biased, whereas basic panels are not. Our analysis cannot assess whether we are in the first or the second

[12] Previous papers indicated that public research and innovation agencies are biased against diverse topics or teams (Langfeldt, 2006, Laudel, 2006, and Banal-Estañol et al., 2019a) or novel projects (Boudreau et al., 2016).

case, that is, whether it is the basic or the applied panels that are biased.

Making statements on the characteristics of the panels that lead to “fair” decisions would require of further analysis (and data). One could argue that specific characteristics, other than quality, for instance, research orientation, gender, or race, should not influence the probability of success (as Hamermesh and Schmidt, 2003, do). But that would be equivalent to assuming that they are (truly) horizontal characteristics. As an alternative approach, one could compare the drivers of success in the ex-ante evaluation and award process to the drivers of success in ex-post performance (as Banal-Estañol et al., 2019a, do). That would require of information on ex-post performance, though.

Independent of this, our paper underscores the importance of the selection of the panel members. Their academic and personal characteristics have a strong influence on the award decisions. For instance, panel members with a basic orientation may penalise applied research. Similarly, male-dominated panels may penalise female applicants. Therefore the selection process may need to assemble a panel that collectively possesses not only sufficient knowledge and expertise but also enough diversity both in terms of research-related and demographic characteristics.

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Appendix A

Performance Evaluation and Collaboration Matching between Industry and Academic

A.1 Proofs in the Sensitivity Scenario

Proof of Proposition 1.1: I separate this proof in three parts. For a pair (p_i, a_j), first, I solve the optimal contract if p_i discontinues the project under a bad signal. Second, I solve the optimal contract if p_i continues the project when a bad signal reveals. Third, I compare the expected profits in these two cases, and the equilibrium contract is the one, which yields a higher expected profit.

(1) Assuming that the company p_i discontinues the project when receiving b, the optimal contract is the solution of the following:

$$\max_{e, w_{ij}^g, w_{ij}^b} \quad G \underbrace{\alpha_i \gamma_j e}_{\pi(G,g)} + B \underbrace{(1-\beta)(1-\gamma_j e)}_{\pi(B,g)} - w_{ij}^g \underbrace{[\alpha_i \gamma_j e + (1-\beta)(1-\gamma_j e)]}_{\pi(g)} - w_{ij}^b \underbrace{[1 - \alpha_i \gamma_j e - (1-\beta)(1-\gamma_j e)]}_{\pi(b)}$$

$$s.t.\quad w_{ij}^g[\alpha_i\gamma_j e+(1-\beta)(1-\gamma_j e)]+w_{ij}^b[1-\alpha_i\gamma_j e-(1-\beta)(1-\gamma_j e)]-\frac{1}{2}e^2\geq\underline{U}\qquad(PC)$$

$$e=(\alpha_i+\beta-1)\gamma_j(w_{ij}^g-w_{ij}^b)\quad(ICC)$$

$$w_{ij}^b\geq 0\quad(LLC)$$

Let X_{ij} denote $[G\alpha_i-B(1-\beta)](\alpha_i+\beta-1)\gamma_j{}^2$ to reduce the length of expressions, by Kuhn-Tucker conditions, there are only two possible cases:

Case 1: LLC is binding but PC is not, the payment schemes, effort, and a_j's and p_i's expected utilities are: $w_{ij}^g=\frac{X_{ij}-(1-\beta)}{2(\alpha_i+\beta-1)^2\gamma_j{}^2}$, $w_{ij}^b=0$, $e_j(W_{ij}(\underline{U}_j);a_j)=\frac{X_{ij}-(1-\beta)}{2(\alpha_i+\beta-1)\gamma_j}$, $Eu_j=\frac{(X_{ij}+3(1-\beta))(X_{ij}-(1-\beta))}{8(\alpha_i+\beta-1)^2\gamma_j{}^2}=\hat{U}(\alpha_i,\gamma_j)>\underline{U}_j$, $E\hat{v}_i=\frac{[X_{ij}-(1-\beta)]^2}{4(\alpha_i+\beta-1)^2\gamma_j{}^2}+B(1-\beta)$. This case is only possible when $\underline{U}_j\leq\hat{U}(\alpha_i,\gamma_j)$.

Case 2: Both LLC and PC are binding, the academic's expected utility is $Eu_j=\underline{U}_j$, and $w_{ij}^b=0$. From PC, I solve the wage $w_{ij}^g=\frac{\sqrt{(1-\beta)^2+2(\alpha_i+\beta-1)^2\gamma_j{}^2\underline{U}_j}-(1-\beta)}{(\alpha_i+\beta-1)^2\gamma_j{}^2}$. Let Y_{ij} denote $\sqrt{(1-\beta)^2+2(\alpha_i+\beta-1)^2\gamma_j{}^2Eu_j}$, then the effort and expected profit are: $e_j(W_{ij}(\underline{U}_j);a_j)=\frac{Y_{ij}-(1-\beta)}{(\alpha_i+\beta-1)\gamma_j}$, $E\hat{v}_i=\frac{(X_{ij}-Y_{ij})(Y_{ij}-(1-\beta))}{(\alpha_i+\beta-1)^2\gamma_j{}^2}+B(1-\beta)$. This case is possible when $\underline{U}_j\geq\hat{U}(\alpha_i,\gamma_j)$, which implies that

$$Y_{ij}\geq\frac{X_{ij}+(1-\beta)}{2}.\qquad(1)$$

Moreover, the expected profit must satisfy ACC_p, i.e., $E\hat{v}_i\geq 0$. Solving this inequality as a function of Y_{ij}:

$$\frac{(X_{ij}+(1-\beta))-\sqrt{(X_{ij}-(1-\beta))^2+4(\alpha_i+\beta-1)^2\gamma_j{}^2(1-\beta)B}}{2}\leq Y_{ij}\quad\&$$

$$Y_{ij}\leq\frac{(X_{ij}+(1-\beta))+\sqrt{(X_{ij}-(1-\beta))^2+4(\alpha_i+\beta-1)^2\gamma_j{}^2(1-\beta)B}}{2}.\qquad(2)$$

Therefore, Y_{ij} has to satisfy (1) and (2) simultaneously, which implies that:

$$\hat{U}_j(\alpha_i,\gamma_j)=\frac{(X_{ij}+3(1-\beta))(X_{ij}-(1-\beta))}{8(\alpha_i+\beta-1)^2\gamma_j{}^2}\leq\underline{U}_j\leq\ldots$$

$$\cdots \frac{[X_{ij}+(1-\beta)+\sqrt{(X_{ij}-(1-\beta))^2+4(\alpha_i+\beta-1)^2\gamma_j{}^2(1-\beta)B}]^2-4(1-\beta)^2}{8(\alpha_i+\beta-1)^2\gamma_j{}^2} = \tilde{U}(\alpha_i,\gamma_j) \tag{3}$$

Thus, academic a_j's reservation utility should be lower than $\tilde{U}(\alpha_i,\gamma_j)$. Let me summarize the contract in the following way: when $\underline{U}_j \le \tilde{U}(\alpha_i,\gamma_j)$, $Eu_j = \max\{\hat{U}_j(\alpha_i,\gamma_j),\underline{U}_j\}$; the payment scheme, effort and expected profit are:

$$w^g_{ij} = \frac{Y_{ij}-(1-\beta)}{(\alpha_i+\beta-1)^2\gamma_j{}^2},\ w^b_{ij}=0;$$

$$e_{ij}(W_{ij}(\underline{U}_j);p_i) = \frac{Y_{ij}-(1-\beta)}{(\alpha_i+\beta-1)\gamma_j};$$

$$E\hat{v}_i(W_{ij}(\underline{U}_j);p_i) = \frac{(X_{ij}-Y_{ij})(Y_{ij}-(1-\beta))}{(\alpha_i+\beta-1)^2\gamma_j{}^2}+B(1-\beta).$$

(2) Assuming that the company continues the project under signal b. I will not investigate the details of this contract but only discuss the key element, which is the expected profit $E\tilde{v}_i$. The maximization problem is:

$$\max_{e,w^g_{ij},w^b_{ij}} \quad G\underbrace{\gamma_j e}_{\pi(G)} + B\underbrace{(1-\gamma_j e)}_{\pi(B)} - w^g_{ij}\underbrace{[\alpha_i\gamma_j e+(1-\beta)(1-\gamma_j e)]}_{\pi(g)} - w^b_{ij}\underbrace{[1-\alpha_i\gamma_j e-(1-\beta)(1-\gamma_j e)]}_{\pi(b)}$$

$$s.t. \quad w^g_{ij}[\alpha_i\gamma_j e+(1-\beta)(1-\gamma_j e)]+w^b_{ij}[1-\alpha_i\gamma_j e-(1-\beta)(1-\gamma_j e)]-\frac{1}{2}e^2 \ge \underline{U}_j \tag{PC}$$

$$e = (\alpha_i+\beta-1)\gamma_j(w^g_{ij}-w^b_{ij}) \quad (ICC)$$

$$w^b_{ij} \ge 0 \quad (LLC)$$

Case 1: LLC is binding but PC is not, let $\tilde{X}_{ij}$ denote $(G-B)(\alpha_i+\beta-1)\gamma_j{}^2$, the expected profit is: $E\tilde{v}_i = \frac{[\tilde{X}_{ij}-(1-\beta)]^2}{4(\alpha_i+\beta-1)^2\gamma_j^2}+B$.
Case 2: Both LLC and PC are binding, $Eu_j = \underline{U}_j$. Solving the expected profit, which is: $E\tilde{v}_i = \frac{(\tilde{X}_{ij}-Y_{ij})(Y_{ij}-(1-\beta))}{(\alpha_i+\beta-1)^2\gamma_j^2}+B$.
Note that when $\underline{U}_j = \frac{(\tilde{X}_{ij}+3(1-\beta))(\tilde{X}_{ij}-(1-\beta))}{8(\alpha_i+\beta-1)^2\gamma_j^2}$, **Case 1** and **Case 2** coincide. Thus, writing the expected profit as a function of Eu_j. The expected utility is

$$Eu_j = \max\{\frac{(\tilde{X}_{ij}+3(1-\beta))(\tilde{X}_{ij}-(1-\beta))}{8(\alpha_i+\beta-1)^2\gamma_j^2}, \underline{U}_j\}$$

, then

$$E\tilde{v}_i = \frac{(\tilde{X}_{ij}-Y_{ij})(Y_{ij}-(1-\beta))}{(\alpha_i+\beta-1)^2\gamma_j^2} + B.$$

Comparing the expected profits $E\hat{v}_i$ and $E\tilde{v}_i$, solving the inequality $E\hat{v}_i - E\tilde{v}_i \geq 0$ as a function of Y_{ij}, which implies:

$$Y_{ij} \leq \frac{(1-\alpha_i)^2 G - \beta^2 B}{(1-\alpha_i)G - \beta B}. \tag{4}$$

By (2) and Assumption 1.1, $Y_{ij} \leq X_{ij} \leq (\alpha_i+\beta-1)$. Besides, $(\alpha_i+\beta-1) \leq \frac{(1-\alpha_i)^2 G-\beta^2 B}{(1-\alpha_i)G-\beta B}$ because $|B| \geq G$. Therefore, (4) always holds and $E\hat{v}_i \geq E\tilde{v}_i$. The equilibrium contract is the one in part (1), where the company abandons the project when signal b reveals. ■

Proof of Lemma 1.1: Inequality (2):

$$Y_{ij} \leq \frac{(X_{ij}+(1-\beta)) + \sqrt{(X_{ij}-(1-\beta))^2 + 4(\alpha_i+\beta-1)^2 {\gamma_j}^2 (1-\beta)B}}{2} \tag{5}$$

Note that, if this inequality does not exists, the expected profit is always negative. Thus, a condition such that (5) holds is:

$$(X_{ij}-(1-\beta))^2 + 4(\alpha_i+\beta-1)^2 {\gamma_j}^2 (1-\beta)B \geq 0 \Rightarrow$$

$${\gamma_j}^2 \geq \frac{(1-\beta)[G\alpha_i - (2\alpha_i+\beta-1)B + 2\sqrt{\alpha_i(\alpha_i+\beta-1)(G-B)(-B)}]}{[G\alpha_i - B(1-\beta)]^2(\alpha_i+\beta-1)} = \hat{\gamma}(\alpha_i)^2 \tag{6}$$

$\hat{\gamma}(\alpha_i)$ is the productivity of the academic such that $E\hat{v}_i = 0$ and $\tilde{U}(\alpha_i, \hat{\gamma}(\alpha_i)) = \hat{U}(\alpha_i, \hat{\gamma}(\alpha_i))$. Thus, p_i will not form a partnership with any academic with $\gamma_j < \hat{\gamma}(\alpha_i)$. Let $\hat{\gamma}_j$ denote $\hat{\gamma}(\bar{\alpha}_i)$ and the academic with $\gamma_j < \hat{\gamma}_j$ cannot be hired. Since $(X_{ij}-(1-\beta))^2 + 4(\alpha_i+\beta-1)^2 {\gamma_j}^2 (1-\beta)B$ is strictly increasing in α_i and γ_j, then $\frac{d\hat{\gamma}_j}{d\alpha_i} < 0$. By Assumption 1.1, we have $\bar{\gamma}_j \leq \frac{1}{[G\alpha_i - B(1-\beta)]}$. Therefore, $\hat{\gamma}_j$ should be lower than $\frac{1}{[G\alpha_i - B(1-\beta)]}$, which implies that $(\alpha_i + 2\beta - 2) > 0$. This condition for (α_i, β) is essential. ■

Proof of Proposition 1.2: We have to identify the sign of SC for any possible levels of $\underline{U}_j$. When $\underline{U}_j \leq \hat{U}(\alpha_i, \gamma_j)$, $\frac{\partial E\hat{v}_i}{\partial \underline{U}_j} = 0$, thus, by SC condition if the cross partial derivative $\frac{\partial^2 E\hat{v}_i}{\partial \alpha_i \partial \gamma_j}$ is positive, then the matching is PAM.

$$\frac{\partial^2 E\hat{v}_i}{\partial \alpha_i \partial \gamma_j} = \frac{G(\alpha_i + \beta - 1)^2 \gamma_j^2 X_{ij} + (1-\beta)}{(\alpha_i + \beta - 1)^3 \gamma_j^3} > 0.$$

Therefore, in the case where the reservation utility is low, the matching is PAM. When $\hat{U}(\alpha_i, \gamma_j) \leq \underline{U}_j \leq \tilde{U}(\alpha_i, \gamma_j)$:

$$\frac{\partial E\hat{v}_i}{\partial \gamma_j} = \frac{(Y_{ij} - Z_i)[X_{ij}(Y_{ij} + Z_i) - Y_{ij} Z_i + Z_i^2]}{(\alpha_i + \beta - 1)^2 \gamma_j^3 Y_{ij}}; \quad \frac{\partial E\hat{v}_i}{\partial \underline{U}_j} = -\frac{2Y_{ij} - X_{ij} - Z_i}{Y_{ij}};$$

$$\frac{\partial^2 E\hat{v}_i}{\partial \alpha_i \partial \gamma_j} = \frac{\begin{array}{c} G(\alpha_i + \beta - 1)^2 \gamma_j^2 (Y_{ij}^2 - Z_i^2) Y_{ij}^2 + \ldots \\ \ldots + Z_i (Y_{ij} - Z_i)[X_{ij} Y_{ij} Z_i + X_{ij} Z_i^2 + (Y_{ij} - Z_i)(Y_{ij}^2 - 2Y_{ij} Z_i - Z_i^2)] \end{array}}{(\alpha_i + \beta - 1)^3 \gamma_j^3 Y_{ij}^3};$$

$$\frac{\partial^2 E\hat{v}_i}{\partial \alpha_i \partial \underline{U}_j} = \frac{G(\alpha_i + \beta - 1)^2 \gamma_j^2 Y_{ij}^2 + Z_i (X_{ij} Z_i - Y_{ij}^2 + Z_i^2)}{(\alpha_i + \beta - 1) Y_{ij}^3}.$$

Substituting the derivatives into $SC = \frac{\partial^2 E v_i}{\partial \alpha_i \partial \gamma_j} - \frac{\partial E v_i / \partial \gamma_j}{\partial E v_i / \partial \underline{U}_j} \frac{\partial^2 E v_i}{\partial \alpha_i \partial \underline{U}_j}$, the sign is determined by:

$$SC = \underbrace{G(\alpha_i + \beta - 1)^2 \gamma_j^2 Y_{ij}^2}_{>0} + \underbrace{(Y_{ij} - 2Z_i)}_{>0} \underbrace{(Y_{ij} - X_{ij} - Z_i)}_{<0} Z_i \gtrless 0.$$

I will prove that the sign of this expression is always positive. First, since $Y_{ij} > (Y_{ij} - 2Z_i)$, if $G(\alpha_i + \beta - 1)^2 \gamma_j^2 Y_{ij}^2 + Y_{ij}(Y_{ij} - X_{ij} - Z_i) Z_i > 0$, then the sign is always positive. Second, remember that $Y_{ij} \geq \frac{X_{ij} + Z_i}{2}$, and $G(\alpha_i + \beta - 1)^2 \gamma_j^2 Y_{ij} + (Y_{ij} - X_{ij} - Z_i) Z_i$ is increasing in Y_{ij}, thus, if I can prove that $G(\alpha_i + \beta - 1)^2 \gamma_j^2 \geq Z_i$, then I will have $G(\alpha_i + \beta - 1)^2 \gamma_j^2 Y_{ij} + (Y_{ij} - X_{ij} - Z_i) Z_i > Z_i Y_{ij} + Z_i (Y_{ij} - X_{ij} - Z_i) = Z_i (2Y_{ij} - X_{ij} - Z_i) > 0$. In consequence, I only need to prove that $G(\alpha_i + \beta - 1)^2 \gamma_j^2 \geq Z_i = (1-\beta)$ for any possible parameter combination $(G, B, \alpha_i, \beta, \gamma_j)$.

To prove $G(\alpha_i+\beta-1)^2\gamma_j^2 \geq Z_i$, let me prove a key condition first, which is $X_{ij} \geq 3Z_i$.

$$X_{ij}-3(1-\beta)>0 \Rightarrow {\gamma_j}^2 > \frac{3(1-\beta)}{(\alpha_i+\beta-1)[G\alpha_i-B(1-\beta)]} \tag{7}$$

From the inequality (6), $\gamma_j \geq \hat{\gamma}_j = \frac{(1-\beta)[G\alpha_i-(2\alpha_i+\beta-1)B+2\sqrt{\alpha_i(\alpha_i+\beta-1)(G-B)(-B)}]}{[G\alpha_i-B(1-\beta)]^2(\alpha_i+\beta-1)}$. I can prove that $\hat{\gamma}_j > \frac{3(1-\beta)}{(\alpha_i+\beta-1)[G\alpha_i-B(1-\beta)]}$.

$$\frac{(1-\beta)[G\alpha_i-(3\alpha_i-1)B+2\sqrt{\alpha_i(\alpha_i+\beta-1)(G-B)(-B)}]}{[G\alpha_i-B(1-\beta)]^2(\alpha_i+\beta-1)}-\frac{3(1-\beta)}{(\alpha_i+\beta-1)[G\alpha_i-B(1-\beta)]} \gtrless 0 \equiv$$

$$\underbrace{[(3\alpha_i+4\beta-4)(-B)-G\alpha_i]}_{\gtrless 0}\underbrace{[(1-\beta)(-B)+G\alpha_i]}_{>0} \gtrless 0$$

From the proof of Lemma 1.1, $(\alpha_i+2\beta-2)>0$, and $|B| \geq G$ then:

$$\underbrace{[(3\alpha_i+4\beta-4)(-B)-G\alpha_i]}_{>0}\underbrace{[(1-\beta)(-B)+G\alpha_i]}_{>0} > 0 \tag{8}$$

Then with this condition, let us continue proving $G(\alpha_i+\beta-1)^2\gamma_j^2 \geq Z_i$. If I can prove that $G(\alpha_i+\beta-1)^2\gamma_j^2 > \frac{1}{3}X_{ij} \geq Z_i$, the sign is always positive. That is,

$$G(\alpha_i+\beta-1)^2\gamma_j^2 > \frac{1}{3}[G\alpha_i-B(1-\beta)](\alpha_i+\beta-1)\gamma_j^2 \iff G(\alpha_i+\beta-1) \geq \frac{1}{3}[G\alpha_i-B(1-\beta)]$$

$$\iff G(\frac{2}{3}\alpha_i+\beta-1)+B\frac{(1-\beta)}{3} \geq 0 \tag{9}$$

From Assumption 1.1, $[G\bar{\alpha}_i-B(1-\beta)]\bar{\gamma}_j^2 \leq 1 \Rightarrow \gamma^2 \leq \bar{\gamma}^2 = \frac{1}{[G\bar{\alpha}_i-B(1-\beta)]} < \frac{1}{[G\alpha_i-B(1-\beta)]}$. In addition, γ_j has to satisfy inequality (6), that is $\hat{\gamma}(\alpha_i)^2 \leq \gamma_j^2 \leq \bar{\gamma}^2 < \frac{1}{[G\alpha_i-B(1-\beta)]}$, otherwise, there is no well-defined market. This condition $\hat{\gamma}(\alpha_i)^2 \leq \frac{1}{[G\alpha_i-B(1-\beta)]}$ implies that:

$$1-\frac{(1-\beta)[G\alpha_i-(2\alpha_i+\beta-1)B+2\sqrt{\alpha_i(\alpha_i+\beta-1)(G-B)(-B)}]}{[G\alpha_i-B(1-\beta)](\alpha_i+\beta-1)} \geq 0.$$

By simplification, I have

$$G(\alpha_i+2\beta-2)+B(1-\beta) \geq \frac{2(1-\beta)}{\alpha}\sqrt{\alpha_i(\alpha_i+\beta-1)(G-B)(-B)} > 0 \Rightarrow$$

$$G(\frac{1}{2}\alpha_i+\beta-1)+B\frac{(1-\beta)}{2}>0.$$

And since $G(\frac{2}{3}\alpha_i+\beta-1)+B\frac{(1-\beta)}{3}>G(\frac{1}{2}\alpha_i+\beta-1)+B\frac{(1-\beta)}{2}>0$, inequality (9) always satisfies, which implies that the single-crossing condition is always positive and the matching in the market equilibrium is always PAM for any possible homogeneous β. ■

A.2 Proofs in the Specificity Scenario

Proof of Proposition 1.3: The proof is the same as the proof of Proposition 1.1, we only need to change the heterogeneity from α to β_i. In addition, firms always choose to abandon the project when receiving a bad signal b from the evaluation.

Proof of Lemma 1.2: Using notations X_{ij} and Y_{ij} to simplify the expressions, $X_{ij}=[G\alpha-B(1-\beta_i)](\alpha+\beta_i-1)\gamma_j^2$, and $Y_{ij}=\sqrt{(1-\beta_i)^2+2(\alpha+\beta_i-1)^2\gamma_j^2Eu_j}$. Note that

$$Y_{ij}\leq\frac{(X_{ij}+(1-\beta_i))+\sqrt{(X_{ij}-(1-\beta_i))^2+4(\alpha+\beta_i-1)^2{\gamma_j}^2(1-\beta_i)B}}{2}\tag{10}$$

Note that, if this inequality does not exists, the expected profit is always negative. Thus, a condition such that the inequality (10) exists is:

$$(X_{ij}-(1-\beta_i))^2+4(\alpha+\beta_i-1)^2{\gamma_j}^2(1-\beta_i)B\geq 0\tag{11}$$

Inequality (11) implies:

$${\gamma_j}^2\geq\frac{(1-\beta_i)[G\alpha-(2\alpha+\beta_i-1)B+2\sqrt{\alpha(\alpha+\beta_i-1)(G-B)(-B)}]}{[G\alpha-B(1-\beta_i)]^2(\alpha+\beta_i-1)}=\hat{\gamma}(\beta_i)^2\tag{12}$$

Note that when $\gamma_j=\hat{\gamma}(\beta_i)$, $E\hat{v}_i=0$ and $\tilde{U}(\beta_i,\hat{\gamma}(\beta_i))=\hat{U}(\beta_i,\hat{\gamma}(\beta_i))$. Thus, p_i will not form a partnership with any academic, who has productivity lower than $\hat{\gamma}(\beta_i)$. Let $\hat{\gamma}_j$ denote $\hat{\gamma}(\bar{\beta}_i)$ and the academic with $\gamma_j<\hat{\gamma}_j$ cannot be hired. The left hand side of inequality (11) strictly increases in β_i and γ_j, therefore, $\frac{d\hat{\gamma}_j}{d\beta_i}<0$. Similar to the proof of Lemma 1.1, under Assumption 1.2, the parameters (α, β_i) have to satisfy $(\alpha + 2\beta_i - 2) > 0$. Otherwise, there is no collaboration in the market. ■

Proof of Proposition 1.4: There are two possible cases depending on $\underline{U}_j$: (1) $\underline{U}_j \leq \hat{U}(\beta_i, \gamma_j)$, the expected profit does not depend on $\underline{U}_j$; (2) $\underline{U}_j > \hat{U}(\beta_i, \gamma_j)$ and $Eu_j = \underline{U}_j$, the expected profit depends on $\underline{U}_j$. Before further proving this proposition, let me show that case (1) never exist by the following Remark A.1

Remark A.1. *In the specificity market, the threshold $\hat{U}(\beta_i, \gamma_j)$ decreases in β_i.*

Proof of Remark A.1: The first order derivative of $\hat{U}(\beta_i, \gamma_j)$ w.r.t. β_i is:

$$\frac{\partial \hat{U}(\beta_i, \gamma_j)}{\partial \beta_i} = \frac{\overbrace{B(X_{ij} + (1-\beta_i))(\alpha + \beta_i - 1)^2 \gamma_j^2}^{<0} - \overbrace{(X_{ij} - 3(1-\beta_i))}^{>0?}}{4(\alpha + \beta_i - 1)^3 \gamma_j^2}.$$

From the Proof of Lemma 1.2, we have $(\alpha + 2\beta_i - 2) > 0$, and we have the assumption $|B| \geq G$, then I can also obtain $(X_{ij} - 3(1-\beta_i)) > 0$ by following the same steps to get inequality (7) and (8). Therefore, $\frac{\partial \hat{U}(\beta_i, \gamma_j)}{\partial \beta_i} < 0$.

By Remark A.1, $\hat{U}(\beta_i, \gamma_j)$ decreases in β_i, so in the competition, a better company has to ensure a better academic at least $\underline{U}_j > \hat{U}(\beta_i, \gamma_j)$. In consequence, Case (1) never exist in this scenario. I only need to show that when $\underline{U}_j > \hat{U}(\beta_i, \gamma_j)$, the SC is negative, which implies NAM. Let notation Z_i denote $(1-\beta_i)$ to reduce the length of expressions. I first solve all derivatives needed in SC condition:

$$\frac{\partial E\hat{v}_i}{\partial \gamma_j} = \frac{(Y_{ij} - Z_i)[X_{ij}(Y_{ij} + Z_i) - Y_{ij} Z_i + Z_i^2]}{(\alpha + \beta_i - 1)^2 \gamma_j{}^3 Y_{ij}} > 0,$$

$$\frac{\partial E\hat{v}_i}{\partial \underline{U}_j} = -\frac{2Y_{ij} - X_{ij} - Z_i}{Y_{ij}} < 0,$$

$$\frac{\partial^2 E\hat{v}_i}{\partial \beta_i \partial \gamma_j} = \frac{\begin{array}{l} B(\alpha + \beta_i - 1)^2 \gamma_j{}^2 (Y_{ij}^2 - Z_i^2) Y_{ij}^2 + \ldots \\ \ldots + \alpha (Y_{ij} - Z_i)[X_{ij} Z_i^2 + X_{ij} Y_{ij} Z_i + (Y_{ij} - Z_i)(Y_{ij}^2 - 2Y_{ij} Z_i - Z_i^2)] \end{array}}{(\alpha + \beta_i - 1)^3 \gamma_j{}^3 Y_{ij}^3},$$

$$\frac{\partial^2 E\hat{v}_i}{\partial \beta_i \partial \underline{U}_j} = \frac{B(\alpha + \beta_i - 1)^2 \gamma_j{}^2 Y_{ij}^2 + \alpha (X_{ij} Z_i - Y_{ij}^2 + Z_i^2)}{(\alpha + \beta_i - 1) Y_{ij}^3}.$$

Substituting the derivatives into $SC = \frac{\partial^2 Ev_i}{\partial\beta_i\partial\gamma_j} - \frac{\partial Ev_i/\partial\gamma_j}{\partial Ev_i/\partial \underline{U}_j}\frac{\partial^2 Ev_i}{\partial\beta_i\partial\underline{U}_j}$, by simplification, the sign of SC is determined by:

$$\underbrace{B(\alpha+\beta_i-1)^2\gamma_j^2 Y_{ij}^2}_{<0} + \alpha\underbrace{(Y_{ij}-2Z_i)}_{>0}\underbrace{(Y_{ij}-Z_i-X_{ij})}_{<0} < 0 \tag{12}$$

Inequality (10) and inequality $(X_{ij}-3(1-\beta_i))>0$ imply that $(Y_{ij}-Z_i-X_{ij})<0$ and $(Y_{ij}-2Z_i)>0$, respectively. Then SC is always negative for any possible reservation utility $\underline{U}_j$. The equilibrium matching is NAM. ■

A.3 Proofs in the Symmetry Scenario

Proof of Proposition 1.5: The proof is the same as the proof of Proposition 1.1, we only need to change the heterogeneity to $\alpha_i = \beta_i$. In addition, firms always choose to abandon the project when receiving a bad signal b from the evaluation. ■

Proof of Lemma 1.3: Similarly, I can obtain the condition for γ_j as inequalities (6) and (10). Using notations $\hat{X}_{ij}$ and $\hat{Y}_{ij}$ to simplify the expressions, $\hat{X}_{ij} = [G\alpha_i - B(1-\alpha_i)](2\alpha_i-1){\gamma_j}^2$, $\hat{Y}_{ij} = \sqrt{(1-\alpha_i)^2 + 2(2\alpha_i-1)^2{\gamma_j}^2 Eu_j}$. Note that the only difference is the heterogeneity, which is $\alpha_i = \beta_i$ in symmetry scenario.

$$\hat{Y}_{ij} \leq \frac{(\hat{X}_{ij}+(1-\alpha_i)) + \sqrt{(\hat{X}_{ij}-(1-\alpha_i))^2 + 4(2\alpha_i-1)^2{\gamma_j}^2(1-\alpha_i)B}}{2} \tag{13}$$

The condition such that inequality (13) exists is the following:

$$(\hat{X}_{ij}-(1-\alpha_i))^2 + 4(2\alpha_i-1)^2{\gamma_j}^2(1-\alpha_i)B \geq 0 \Rightarrow$$

$${\gamma_j}^2 \geq \frac{(1-\alpha_i)[G\alpha_i-(3\alpha_i-1)B + 2\sqrt{\alpha_i(2\alpha_i-1)(G-B)(-B)}]}{[G\alpha_i - B(1-\alpha_i)]^2(2\alpha_i-1)} = \hat{\gamma}(\alpha_i)^2 \tag{14}$$

Note that $\hat{\gamma}(\alpha_i)$ is the productivity of the academic such that $E\hat{v}_i = 0$ and $\tilde{U}(\alpha_i, \hat{\gamma}(\alpha_i)) =$

$\hat{U}(\alpha_i, \hat{\gamma}(\alpha_i))$. Thus, p_i will not form a partnership with any academic with $\gamma_j < \hat{\gamma}(\alpha_i)$. Let $\hat{\gamma}_j$ denote $\hat{\gamma}(\bar{\alpha}_i)$ and the academic with $\gamma_j < \hat{\gamma}_j$ cannot be hired. Again, Assumption 1.3 and inequality (13) implies $(3\alpha_i - 2) > 0$. ■

Proof of Proposition 1.6: Similarly, there are two possibilities depending on the level of $\underline{U}_j$. (1) $\underline{U}_j \leq \hat{U}(\beta_i, \gamma_j)$, the expected profit does not depend on $\underline{U}_j$; (2) $\underline{U}_j > \hat{U}(\beta_i, \gamma_j)$ and $Eu_j = \underline{U}_j$, the expected profit depends on $\underline{U}_j$. Before further proving this proposition, let me show that case (1) never exist by the following Remark A.2.

Remark A.2. *In the symmetry scenario, $\hat{U}(\alpha_i, \gamma_j)$ decreases in α_i.*

Proof of Remark A.2:

$$\frac{\partial \hat{U}(\alpha_i, \gamma_j)}{\partial \alpha_i} = \frac{\overbrace{(G+B)(2\alpha_i - 1)^2 \gamma_j^2 (\hat{X}_{ij} + (1-\alpha_i))}^{<0} - \overbrace{(\hat{X}_{ij} - 3(1-\alpha_i))}^{>0?}}{4(2\alpha_i - 1)^3 \gamma_j^2} < 0.$$

From the Proof of Lemma 1.3, we have $(3\alpha_i - 2) > 0$, and we have the assumption $|B| \geq G$, then I can also obtain $(X_{ij} - 3(1-\alpha_i)) > 0$ by following the same steps to get inequality (7) and (8). Therefore, $\frac{\partial \hat{U}(\alpha_i, \gamma_j)}{\partial \alpha_i} < 0$.

By Remark A.2, $\hat{U}(\alpha_i, \gamma_j)$ always decreases in α_i. In the competition, a better company has to guarantee at least $\underline{U}_j > \hat{U}(\alpha_i, \gamma_j)$. Therefore, case (1) never exist. I only need to explore the sign of SC when $\underline{U}_j > \hat{U}(\alpha_i, \gamma_j)$. The derivatives of the expected profit are the following (to reduce the expressions' length, I use notation $\hat{Z}_i = (1-\alpha_i)$):

$$\frac{\partial E\hat{v}_i}{\partial \gamma_j} = \frac{(\hat{Y}_{ij} - \hat{Z}_i)[\hat{X}_{ij}(\hat{Y}_{ij} + \hat{Z}_i) - \hat{Y}_{ij}\hat{Z}_i + \hat{Z}_i^2]}{(2\alpha_i - 1)^2 \gamma_j{}^3 \hat{Y}_{ij}} > 0;$$

$$\frac{\partial E\hat{v}_i}{\partial \underline{U}_j} = -\frac{2\hat{Y}_{ij} - \hat{X}_{ij} - \hat{Z}_i}{\hat{Y}_{ij}} < 0;$$

$$\frac{\partial^2 E\hat{v}_i}{\partial \alpha_i \partial \gamma_j} = \frac{\begin{array}{c}(G+B)(2\alpha_i - 1)^2 \gamma_j{}^2 (\hat{Y}_{ij}^2 - \hat{Z}_i^2)\hat{Y}_{ij}^2 + \ldots \\ \ldots + (\hat{Y}_{ij} - \hat{Z}_i)[\hat{X}_{ij}\hat{Z}_i^2 + \hat{X}_{ij}\hat{Y}_{ij}\hat{Z}_i + (\hat{Y}_{ij} - \hat{Z}_i)(\hat{Y}_{ij}^2 - 2\hat{Y}_{ij}\hat{Z}_i - \hat{Z}_i^2)]\end{array}}{(2\alpha_i - 1)^3 \gamma_j{}^3 \hat{Y}_{ij}^3};$$

$$\frac{\partial^2 E\hat{v}_i}{\partial \alpha_i \partial \underline{U}_j} = \frac{(G+B)(2\alpha_i - 1)^2 \gamma_j{}^2 \hat{Y}_{ij}^2 + \hat{X}_{ij}\hat{Z}_i - (\hat{Y}_{ij}^2 - \hat{Z}_i^2)}{(2\alpha_i - 1)\hat{Y}_{ij}^3}.$$

Substituting the derivatives into $SC = \frac{\partial^2 Ev_i}{\partial \alpha_i \partial \gamma_j} - \frac{\partial Ev_i/\partial \gamma_j}{\partial Ev_i/\partial \underline{U}_j} \frac{\partial^2 Ev_i}{\partial \alpha_i \partial \underline{U}_j}$. Simplifying, I have the sign of SC is determined by:

$$\underbrace{(G+B)(2\alpha_i - 1)^2 \gamma_j{}^2 \hat{Y}_{ij}^2}_{\leq 0} + (\hat{Y}_{ij} - 2\hat{Z}_i)\underbrace{(\hat{Y}_{ij} - \hat{X}_{ij} - \hat{Z}_i)}_{<0}.$$

Inequality (13) and $(\hat{X}_{ij} - 3(1-\alpha_i)) > 0$ imply that $(\hat{Y}_{ij} - \hat{X}_{ij} - \hat{Z}_i) < 0$ and $(\hat{Y}_{ij} - 2\hat{Z}_i) > 0$, respectively. Therefore, $SC < 0$, the equilibrium matching is NAM. ■

A.4 Proof for the Relationship between the Remuneration and the Productivity

Proof of Proposition 1.7: In the sensitivity scenario, when $\underline{U}_j \geq \hat{U}(\alpha_i, \gamma_j)$,

$$\frac{dw_{ij}^g}{d\gamma_j} = -\underbrace{\frac{-(Y_{ij} - Z_i)^2}{(\alpha_i + \beta - 1)^2 \gamma_j^3 Y_{ij}}}_{\frac{\partial w_{ij}^g}{\partial \gamma_j}} - \underbrace{\frac{-(Y_{ij} - Z_i)^2}{(\alpha_i + \beta - 1)^3 \gamma_j^2 Y_{ij}} \frac{\bar{\alpha}_i - \underline{\alpha}_i}{\bar{\gamma}_j - \underline{\gamma}_j}}_{\frac{\partial w_{ij}^g}{\partial \alpha_i} \frac{\partial \alpha_i}{\partial \gamma_j}} + \underbrace{\frac{(Y_{ij} - Z_i)[X_{ij}(Y_{ij} - Z_i) - Y_{ij}Z_i + Z_i^2]}{(2Y_{ij} - X_{ij} - Z_i)(\alpha_i + \beta - 1)^2 \gamma_j^3 Y_{ij}}}_{\frac{\partial w_{ij}^g}{\partial \underline{U}_j} \frac{\partial \underline{U}_j}{\partial \gamma_j}}$$

Simplifying,

$$\frac{(Y_{ij} - Z_i)^2[(\alpha_i + \beta - 1)(\bar{\gamma}_j - \underline{\gamma}_j) + \gamma_j(\bar{\alpha}_i - \underline{\alpha}_i)]}{(\alpha_i + \beta - 1)^3 \gamma_j^3 Y_{ij}(\bar{\gamma}_j - \underline{\gamma}_j)} + \frac{(Y_{ij} - Z_i)[X_{ij}(Y_{ij} - Z_i) - Y_{ij}Z_i + Z_i^2]}{(2Y_{ij} - X_{ij} - Z_i)(\alpha_i + \beta - 1)^2 \gamma_j^3 Y_{ij}} \gtrless 0$$

For last term, when $\underline{U}_j \to \hat{U}$, it is positive infinite. If the boundaries of the distribution $(\bar{\gamma}_j - \underline{\gamma}_j) > 0$, the sign of $\frac{dw_{ij}^g}{d\gamma_j}$ is positive. If $\underline{U}_j = \tilde{U}(\alpha_i, \gamma_j)$, the sign of $\frac{dw_{ij}^g}{d\gamma_j}$ is always negative. In consequence, when $\underline{U}_j$ is low enough and distribution of productivity is not too tight (i.e., $(\bar{\gamma}_j - \underline{\gamma}_j) \gg 0$), the wage is always increasing in the academic's productivity, i.e., $\frac{dw_{ij}^g}{d\gamma_j} > 0$. In contrast, if $\underline{U}_j$ is high enough, whatever the distribution of productivity is, $\frac{dw^g_{ij}}{d\gamma_j} < 0$. But when $\underline{U}_j$ is at an intermediate level, the sign depends on both distributions of productivity and evaluation technology and corresponded parameters γ_j and α_i. Then, the sign may be not always positive or negative. Thus, the relationship between w^g_{ij} and γ_j may be non-monotonic. I can prove the results for the other two scenarios in a similar way. ■

A.5 Proof of Proposition 1.8

Let me use expression $Ev(t_i, \gamma_j, \underline{U}_j)$ to denote the company t_i's expected profit when it is matched with γ_j with reservation utility $\underline{U}_j$. Suppose that $Ev(\beta, \gamma_1, \hat{U}(\beta, \gamma_2)) > 0$, otherwise, company β is always unmatched. Assume that $\gamma_1 > \gamma_2$. By solving the following equations, we obtain $\underline{U}(\beta, \gamma_1)$ and $\underline{U}(\alpha, \gamma_1)$:

$$Ev(\beta, \gamma_1, \underline{U}(\beta, \gamma_1)) = \max\{0, Ev(\beta, \gamma_2, \hat{U}(\beta, \gamma_2))\} \Rightarrow$$

$$\underline{U}(\beta, \gamma_1) = \frac{Y^{\star 2} - (1-\beta)^2}{2\beta^2\gamma_1^2} \text{ if } Ev(\beta, \gamma_2, \hat{U}(\beta, \gamma_2)) > 0,$$

$$\underline{U}(\beta, \gamma_1) = \tilde{U}(\beta, \gamma_1) \text{ if } Ev(\beta, \gamma_2, \hat{U}(\beta, \gamma_2)) \le 0,$$

where $Y^\star = \frac{\hat{X}_1 + (1-\beta) + \sqrt{(\hat{X}_1 + (1-\beta))^2 - (\hat{X}_2 + (1-\beta))^2 \gamma_1^2/\gamma_2^2}}{2}$, $\hat{X}_1 = [G - B(1-\beta)]\beta\gamma_1^2$, $\hat{X}_2 = [G - B(1-\beta)]\beta\gamma_2^2$.

$$Ev(\alpha, \gamma_1, \underline{U}(\alpha, \gamma_1)) = Ev(\alpha, \gamma_2, \hat{U}(\alpha, \gamma_2)) \Rightarrow \underline{U}(\alpha, \gamma_1) = \frac{G^2\alpha^2(\gamma_1 + \sqrt{\gamma_1^2 - \gamma_2^2})^2}{8}.$$

Solving $\underline{U}(\beta, \gamma_1) > \underline{U}(\alpha, \gamma_1)$, we obtain:

$$\alpha < \frac{2\sqrt{Y^{\star 2} - (1-\beta)^2}}{G\beta\gamma_1(\gamma_1 + \sqrt{\gamma_1^2 - \gamma_2^2})} = \alpha(\beta) \text{ if } Ev(\beta, \gamma_2, \hat{U}(\beta, \gamma_2)) > 0,$$

$$\alpha < \frac{2\sqrt{2\tilde{U}(\beta,\gamma_1)}}{G\alpha(\gamma_1 + \sqrt{\gamma_1^2 - \gamma_2^2})} = \alpha(\beta) \text{ if } Ev(\beta,\gamma_2,\hat{U}(\beta,\gamma_2)) \leq 0.$$

Therefore, $\alpha^\star(\beta) = \min\{\alpha(\beta), 1\}$. ■

Appendix B

The Impact of Consumers' Regret on Firms' Decisions in a Durable Good Market

B.1 Proof of the Benchmark Case

Proof of Proposition 2.1: Under Assumption 2.1, at the last stage of the game, the optimal price p_{I2}, as a function of p_{E2}, is the one that maximizes the incumbent's profit at $t = 2$. The optimal response is $p^{\star}_{I2}(p_{E2}) = p_{E2}$ if $p_{E2} \leq v$, and $p^{\star}_{I2}(p_{E2}) = v$ if $p_{E2} > v$. Now I move backward and consider the entrant's decision about optimal price p_{E2} given the price p_{I1} set by the incumbent before, and then I analyze the best strategy of the incumbent at the first stage of the game p_{I1}. I consider two scenarios: $p_{E2} \leq v$; and $p_{E2} > v$, and I show that the solution is of the former form.

(1) **Equilibrium candidate** $p_{E2} \leq v$

If $p_{E2} \leq v$, consumers in the market are the ones with $\theta > \hat{\theta} = \frac{v - p_{I1} + p_{E2}}{\phi q_E}$. The demand for improved version E is $\phi(1 - \hat{\theta})$. The entrant's profit maximization problem is:

$$\max_{p_{E2}} \Pi_E = \max_{p_{E2}} \phi \int_{\frac{v-p_{I1}+p_{E2}}{\phi q_E}}^{1} p_{E2} d\theta$$

From the first order condition (FOC), I have $p_{E2}^{\star}(p_{I1}) = \frac{\phi q_E + p_{I1} - v}{2}$. Substituting $p_{E2}^{\star}$ into $\hat{\theta}$, I obtain $\hat{\theta}(p_{I1}) = \frac{v - p_{I1} + \phi q_E}{2\phi q_E}$, the demand of the incumbent's good at $t = 1$ as a function of p_{I1}. The demand of its good at $t = 2$ is $(1-\phi)(1-\hat{\theta}(p_{I1}))$. Then the incumbent's profit maximization problem at the first stage of the game is:

$$\max_{p_{I1}} \Pi_I = \max_{p_{I1}} \int_0^{\frac{v-p_{I1}+\phi q_E}{2\phi q_E}} p_{I1} d\theta + (1-\phi) \int_{\frac{v-p_{I1}+\phi q_E}{2\phi q_E}}^{1} \frac{\phi q_E + p_{I1} - v}{2} d\theta$$

From the FOC, as a function of q_E and ϕ, I have $p_{I1}^{\star} = \frac{\phi[(2-\phi)q_E + v]}{1+\phi}$, which in turn implies that the equilibrium candidate is $p_{I1}^{\star} = \frac{\phi[(2-\phi)q_E+v]}{1+\phi}$, $p_{I2}^{\star} = p_{E2}^{\star} = \frac{3\phi q_E - v}{2(1+\phi)}$, $\hat{\theta}^{\star} = \frac{v+(2\phi-1)\phi q_E}{2(1+\phi)\phi q_E}$, $\Pi_I^{\star} = \frac{v^2+2(2\phi-1)\phi v q_E+(5-4\phi)\phi^2 {q_E}^2}{4(1+\phi)\phi q_E}$, $\Pi_E^{\star} = \frac{(3\phi q_E - v)^2}{4(1+\phi)^2 q_E}$. Under Assumption 2.1, the conditions such that this equilibrium candidate exists are satisfied:

(a) The demand for the incumbent's good at $t = 1$ is positive, $2v - p_{I1} \geq 0$; (b) Some consumers wait for the second period, and that population is not greater than 1, $0 \leq \hat{\theta} \leq 1$; (c) The entrant can earn positive profits, $p_{E2} \geq 0$; (d) The restriction for this scenario, $v - p_{E2} \geq 0$.

(2) **Equilibrium candidate when** $p_{E2} > v$

Consider $p_{E2} > v$, which implies $p_{I2} = v$. Following the steps as that in the previous case, as functions of q_E and ϕ, I obtain the prices, and the demand, $p_{I1}^{\star\star} = \frac{(2-\phi)v+\phi q_E}{2}$, $p_{E2}^{\star\star} = \frac{3\phi q_E - \phi v}{4}$, $p_{I2}^{\star\star} = v$, $\hat{\theta}^{\star\star} = \frac{v+q_E}{4q_E}$. The conditions for this equilibrium candidate to exist are: (a) $2v - p_{I1} \geq 0$; (b) $0 \leq \hat{\theta} \leq 1$; (c) $p_{E2} \geq 0$; (d) $v - p_{E2} \leq 0$

Condition (d) is violated since $q_E \leq v$, thus, this equilibrium candidate does not exist.

Equilibrium prices, profits, and demand are those in **Case 1**. ■

B.2 Proofs When Action Regret Is Present

Proof of Lemma 2.1: I first prove the following Claim.

Claim B.1. *Under Assumption 2.1, the equilibrium prices and demand for the incumbent's product at $t = 1$ are:*

$$p_{I1}^{\star} = \frac{(2-\phi)\phi(1+r_a)q_E + \phi(1+r_a\phi)v}{(1+\phi)(1+r_a\phi)},\ p_{I2}^{\star} = p_{E2}^{\star} = \frac{3(1+r_a)\phi q_E - (1+r_a\phi)v}{2(1+\phi)(1+r_a\phi)},$$
$$\hat{\theta}^{\star} = \frac{(1+r_a\phi)v + (2\phi-1)(1+r_a)\phi q_E}{2(1+\phi)(1+r_a)\phi q_E}.$$

Proof of Claim B.1: To proof this Claim, following the same steps as that in the proof of Proposition 2.1, I consider two possible cases: $p_{I2}^{\star}(p_{E2}) = p_{E2}$ if $p_{E2} \leq v$, and $p_{I2}^{\star}(p_{E2}) = v$ if $p_{E2} > v$. Then I check the existence of each case.

(1) **Equilibrium candidate** $p_{E2} \leq v$

By backward induction and the entrant's and the incumbent's profit maximization problems, I have the prices, demand for version I at $t = 1$ and profits for this equilibrium candidate.

$p_{I1}^{\star} = \frac{(2-\phi)\phi(1+r_a)q_E+\phi(1+r_a\phi)v}{(1+\phi)(1+r_a\phi)}$, $p_{I2}^{\star} = p_{E2}^{\star} = \frac{3(1+r_a)\phi q_E-(1+r_a\phi)v}{2(1+\phi)(1+r_a\phi)}$,
$\hat{\theta} = \frac{(1+r_a\phi)v+(2\phi-1)(1+r_a)\phi q_E}{2(1+\phi)(1+r_a)\phi q_E}$.

Under Assumption 2.1, the conditions such that this equilibrium candidate exists are satisfied: (a) $u_{E2} = v + \phi\hat{\theta}q_E - p_{E2} \geq 0$, which is equivalent to $u_{I1} \geq 0$; (b) $0 \leq \hat{\theta} \leq 1$; (c) $p_{E2} \geq 0$; (d) $v - p_{E2} \geq 0$.

(2) **Equilibrium candidate** $p_{E2} > v$

Consider the case $p_{E2} > v$, which implies $p_{I2} = v$. Following the same steps, I obtain the prices and the demand $p_{I1}^{\star\star} = \frac{(2-\phi)(1+r_a\phi)v+\phi(1+r_a)q_E}{2(1+r_a\phi)}$, $p_{E2}^{\star\star} = \frac{3(1+r_a)\phi q_E-\phi(1+r_a\phi)v}{4(1+r_a\phi)}$, $\hat{\theta}^{\star\star} = \frac{(1+r_a\phi)v+(1+r_a)q_E}{4(1+r_a)q_E}$. I need to check the existence of this equilibrium candidate, the prices and demand have to satisfy the following conditions: (a) $v + \phi\hat{\theta}q_E - p_{E2} \geq 0$; (b) $0 \leq \hat{\theta} \leq 1$; (c) $p_{E2} \geq 0$; (d) $p_{E2} > v$. Condition (d) is not satisfied since $p_{E2} > v \rightarrow q_E > \frac{(4+\phi)(1+r_a\phi)}{3(1+r_a)\phi}v > v$, which is contradicts with Assumption 2.1. Therefore, **Case 1** is the equilibrium in this scenario.

■

This Claim allows me to analyze the behavior of the equilibrium prices and the demand of version I at $t = 1$, stated in Lemma 2.1. We can obtain that $\frac{\partial p^\star_{I1}}{\partial r_a} > 0$, $\frac{\partial p^\star_{I2}}{\partial r_a} > 0$ and $\frac{\partial p^\star_{E2}}{\partial r_a} > 0$, $\frac{\partial \hat{\theta}^\star}{\partial r_a} < 0$.

■

Proof of Proposition 2.2: With the Claim proven in Lemma 2.1, given the equilibrium prices and demand I obtain the firms' profits in equilibrium included in Proposition 2.2.

■

Remark B.1. *The incumbent's profit at* $t = 1$ *always decreases in* r_a *and that at* $t = 2$ *increases in* r_a.

Proof of Remark B.1: Π_{I2} increases in r_a since more consumers wait for $t = 2$ and p_{I2} is higher. I can obtain Π_{I1} and first order with respect to r_a:

$$\Pi^\star_{I1} = \frac{(2-\phi)(2\phi-1)\phi(1+r_a)^2 q_E^2 + (1+r_a\phi)^2 v^2 + 2(\phi^2-\phi+1)(1+r_a)(1+r_a\phi)q_E v}{2(1+\phi)^2(1+r_a)(1+r_a\phi)q_E},$$

$$\frac{\partial \Pi^\star_{I1}}{\partial r_a} = \frac{(1-\phi)[(2-\phi)(2\phi-1)\phi(1+r_a)^2 q_E^2 - (1+r_a\phi)^2 v^2]}{2(1+\phi)^2(1+r_a)^2(1+r_a\phi)^2 q_E},$$

$$\frac{\partial \Pi^\star_{I1}}{\partial r_a} \gtrless 0 \text{ iff } [\sqrt{(2-\phi)(2\phi-1)\phi}(1+r_a)q_E - (1+r_a\phi)v] \gtrless 0,$$

one can easily have it is always negative under Assumption 2.1. Thus, $\Pi^\star_{I1}$ decreases in r_a. ■

Proof of Proposition 2.3: From the first order of the incumbent's profit with respect to r_a I have:

$$\frac{\partial \Pi^\star_{I}}{\partial r_a} = \frac{(1-\phi)[(5-4\phi)(1+r_a)^2\phi^2 {q_E}^2 - (1+\phi r_a)^2 v^2]}{4(1+\phi)\phi(1+r_a)^2(1+r_a\phi)^2 q_E} \gtrless 0 \Rightarrow$$

$$\underbrace{[q_E\sqrt{5-4\phi} - v]}_{\gtrless 0}\phi r_a \gtrless \underbrace{v - \phi q_E\sqrt{5-4\phi}}_{\gtrless 0}.$$

(1) If $[q_E\sqrt{5-4\phi}-v] \le 0$, which implies that $v-\phi q_E\sqrt{5-4\phi} > 0$, thus, $\frac{\partial \Pi_I}{\partial r_a} < 0$. This case requires $q_E \le \frac{v}{\sqrt{5-4\phi}}$. Using Assumption 2.1: $\phi \ge \frac{13}{20}$ and $q_E \ge \frac{v}{3\phi}$. Therefore, I need $\frac{v}{\sqrt{5-4\phi}} \ge \frac{v}{3\phi} \Rightarrow \phi \ge \frac{5}{9}$. For case (1), I have $q_E \in [\frac{v}{3\phi}, \frac{v}{\sqrt{5-4\phi}}]$.

(2) If $[q_E\sqrt{5-4\phi}-v] \ge 0$ and $v-\phi q_E\sqrt{5-4\phi} \le 0 \Rightarrow q_E \ge \frac{v}{\phi\sqrt{5-4\phi}}$, which implies $\frac{\partial \Pi_I^\star}{\partial r_a} \ge 0$. Notice that $q_E \le v$, thus, case (2) requires $\frac{v}{\phi\sqrt{5-4\phi}} \le v \Rightarrow \phi \ge \frac{\sqrt{17}+1}{8}$. Note that under Assumption 2.1, $\phi \ge \frac{\sqrt{17}+1}{8}$ is satisfied because $\frac{13}{20} > \frac{\sqrt{17}+1}{8}$. The condition guaranteeing the existence of case (2) is: $q_E \in [\frac{v}{\phi\sqrt{5-4\phi}}, v]$.

(3) If $[q_E\sqrt{5-4\phi}-v] \ge 0$ and $v-\phi q_E\sqrt{5-4\phi} \ge 0 \Rightarrow \frac{v}{\sqrt{5-4\phi}} \le q_E \le \frac{v}{\phi\sqrt{5-4\phi}}$. If $r_a \ge \frac{v-\phi q_E\sqrt{5-4\phi}}{\phi(q_E\sqrt{5-4\phi}-v)}$, $\frac{\partial \Pi_I}{\partial r_a} \ge 0$, otherwise $\frac{\partial \Pi_I}{\partial r_a} < 0$. Combined with Assumption 2.1, the conditions such that case (3) exists are: $\frac{13}{20} \le \phi \le 1$ and $\max\{\frac{v}{3\phi}, \frac{v}{\sqrt{5-4\phi}}\} \le q_E \le \min\{v, \frac{v}{\phi\sqrt{5-4\phi}}\}$.

As for the entrant, the first order derivative of its profit with respect to r_a is:

$$\frac{\partial \Pi_E^\star}{\partial r_a} = \frac{(1-\phi)[3(1+r_a)\phi q_E + (1+r_a\phi)v] * [3(1+r_a)\phi q_E - (1+r_a\phi)v]}{4(1+\phi)^2(1+r_a)^2(1+r_a\phi)^2 q_E}$$

Under Assumption 2.1, $\frac{\partial \Pi_E^\star}{\partial r_a}$ is always positive. In addition, we can check that $\frac{\partial^2 \Pi_I^\star}{\partial r_a \partial q_E} > 0$ and $\frac{\partial^2 \Pi_E^\star}{\partial r_a \partial q_E} > 0$, which means that when action regret increases both firms' profits, the positive influence is greater if q_E is higher. But when action regret reduces the incumbent's overall profit, this negative effect is mitigated when q_E is larger. ■

B.3 Proofs When Inaction Regret Is Present

Proof of Lemma 2.2: I first prove the following Claim.

Claim B.2. *Under Assumption 2.1 and 2.2, the equilibrium prices and demands for the incumbent's good at $t = 1$ are:*

$$p_{I1}^\star = \frac{\phi(2-\phi)q_E + \phi[1+(1-\phi)r_i]v}{[1+(1-\phi)r_i](1+\phi)}, \; p_{I2}^\star = p_{E2}^\star = \frac{3\phi q_E - [1+(1-\phi)r_i]v}{2[1+(1-\phi)r_i](1+\phi)}.$$

The demand for product I at $t = 1$ is:

$$\hat{\theta}^{\star} = \frac{[1+(1-\phi)r_i]v + (2\phi-1)\phi q_E}{2(1+\phi)\phi q_E}.$$

Proof of Claim B.2: Under Assumption 2.1 and 2.2, as I did in the proofs of Proposition 2.1, I identify the equilibrium prices and demand from two candidates:

(1) **Equilibrium candidate** $p_{E2} < v$

I follow the same steps in L 1.1, by backward induction, I obtain the prices, demand for incumbent's version I in the first period and profits: $p_{I1}^{\star} = \frac{\phi(2-\phi)q_E + \phi[1+(1-\phi)r_i]v}{[1+(1-\phi)r_i](1+\phi)}$, $p_{I2}^{\star} = p_{E2}^{\star} = \frac{3\phi q_E - [1+(1-\phi)r_i]v}{2[1+(1-\phi)r_i](1+\phi)}$, $\hat{\theta}^{\star} = \frac{[1+(1-\phi)r_i]v+(2\phi-1)\phi q_E}{2(1+\phi)\phi q_E}$, $\Pi_I^{\star} = \frac{[1+(1-\phi)r_i]^2 v^2 + 2(2\phi-1)[1+(1-\phi)r_i]\phi v q_E + (5-4\phi)\phi^2 {q_E}^2}{4[1+(1-\phi)r_i](1+\phi)\phi q_E}$, $\Pi_E^{\star} = \frac{[3\phi q_E - (1+(1-\phi)r_i)v]^2}{4(1+\phi)^2[1+(1-\phi)r_i]q_E}$.

This equilibrium candidate satisfies the following conditions for the existence under Assumption 2.1 and 2.2: a) $2v - p_{I1} \geq 0$; b) $0 \leq \hat{\theta} \leq 1$; c) $p_{E2} \geq 0$; d) $v - p_{E2} \geq 0$.

(2) **Equilibrium candidate when** $p_{E2} > v$

I solve the prices and demand: $p_1^I = \frac{(2-\phi)(1+r_A\phi)v + \phi(1+r_A)q^E}{2(1+r_A\phi)}$, $p_2^E = \frac{3(1+r_A)\phi q^E - \phi(1+r_A\phi)v}{4(1+r_A\phi)}$, $\hat{\theta} = \frac{(1+r_A\phi)v+(1+r_A)q^E}{4(1+r_A)q^E}$. This equilibrium candidate never exist since it will violate the assumption $q_E \leq v$.

Therefore, equilibrium prices and demand are the ones in **Case 1**. ■

Claim B.2 allows me to analyze the characteristics of the prices and demand in equilibrium, which are stated in Lemma 2.2. ■

Proof of Proposition 2.4: By Claim B.2, I obtain the firms' profit at the equilibrium, which are summarized in Proposition 2.4. ■

Remark B.2. *The incumbent's profit at $t = 1$ increases in r_i and that at $t = 2$ decreases in r_i.*

Proof of Remark B.2: $\Pi_{I2}^{\star}$ decreases in r_i since fewer consumers wait for $t = 2$ and price p_{I2} is lower. Then, the incumbent's profit at $t = 1$:

$$\Pi^{\star}_{I1} = \frac{\phi[1+(1-\phi)r_i]^2 v^2 + \phi^2(2\phi-1)(2-\phi)q_E^2 + 2\phi[1+(1-\phi)r_i](\phi^2-\phi+1)q_E v}{2(1+\phi)^2\phi q_E[1+(1-\phi)r_i]},$$

$$\frac{\partial \Pi^{\star}_{I1}}{\partial r_i} = \frac{(1-\phi)\{[1+(1-\phi)r_i]^2 v^2 - \phi(2\phi-1)(2-\phi)q_E^2\}}{2(1+\phi)^2\phi[1+(1-\phi)r_i]^2 q_E},$$

Obviously, $\frac{\partial \Pi^{\star}_{I1}}{\partial r_i}$ is always positive under Assumption 2.1. ■

Proof of Proposition 2.5: The first order derivative of the incumbent's profit with respect to r_i is:

$$\frac{\partial \Pi^{\star}_{I}}{\partial r_i} = \frac{(1-\phi)\overbrace{\{[1+(1-\phi)r_i]v - \sqrt{5-4\phi}\phi q_E\}}^{\gtreqless 0}\overbrace{\{[1+(1-\phi)r_i]v + \sqrt{5-4\phi}\phi q_E\}}^{>0}}{4\phi(1+\phi)[1+(1-\phi)r_i]^2 q_E}$$

The sign of first order derivative depends on $[1+(1-\phi)r_i]v - \sqrt{5-4\phi}\phi q_E$. This term is non-negative if

$$(1-\phi)r_i v \geq \phi q_E\sqrt{5-4\phi} - v$$

(1) If $q_E \leq \frac{v}{\phi\sqrt{5-4\phi}}$, this inequality always holds. Thus, given Assumption 2.2, when $\frac{v}{3\phi} \leq q_E \leq \min\{\frac{v}{\phi\sqrt{5-4\phi}}, v\}$, $\frac{\partial \Pi_I}{\partial r_i} \geq 0$.

(2) When the right hand side of the inequality is positive, that is $\frac{v}{\phi\sqrt{5-4\phi}} < q_E \leq v$, which requires that $\phi \geq \frac{\sqrt{17}+1}{8}$, which is lower than $\frac{13}{20}$. Under this circumstance, $\frac{\partial \Pi_I}{\partial r_i} < 0$ if $r_i < \frac{\phi q_E\sqrt{5-4\phi}-v}{(1-\phi)v} = \hat{r}_i$; $\frac{\partial \Pi_I}{\partial r_i} \geq 0$ if $r_i \geq \hat{r}_i$. Note that $\hat{r}_i < \frac{3\phi q_E - v}{(1-\phi)v}$, thus, threshold $\hat{r}_i$ exists under Assumption 2.2.

The first order derivative of the entrant's profit w.r.t. r_i is:

$$\frac{\partial \Pi^{\star}_{E}}{\partial r_i} = \frac{(1-\phi)\overbrace{\{3\phi q_E - [1+(1-\phi)r_i]v\}}^{\geq 0}\overbrace{\{-3\phi q_E - [1+(1-\phi)r_i v]\}}^{<0}}{4(1+\phi)^2[1+(1-\phi)r_i]^2 q_E} \leq 0.$$

In addition, $\frac{\partial^2 \Pi^{\star}_{I}}{\partial r_i \partial q_E} < 0$ and $\frac{\partial^2 \Pi^{\star}_{E}}{\partial r_i \partial q_E} < 0$. That is, when a higher q_E weakens the positive effect of inaction regret on the incumbent's profit but strengthens the negative impact on both firms' profits. ■

B.4 Proof When Both Regrets Are Present

Proof of Proposition 2.6: The utility functions are as follows:

$$Eu_{I1} = 2v - p_{I1} - \phi r_a(\theta q_E - p_{E2} - v + p_{I1})$$

$$u_{I2} = v - p_{I2}$$

$$Eu_{E2} = v + \phi\theta q_E - p_{E2} - (1-\phi)r_i(v - p_{I1} + p_{E2}).$$

By backward induction, I obtain the equilibrium prices, demand and profits:

$p^\star_{I1} = \frac{\phi(1+\phi r_a+(1-\phi)r_i)v+(2-\phi)\phi(1+r_a)q_E}{(1+\phi)(1+\phi r_a+(1-\phi)r_i)}$, $p^\star_{I2} = p^\star_{E2} = \frac{3\phi(1+r_a)q_E-(1+\phi r_a+(1-\phi)r_i)v}{2(1+\phi r_a+(1-\phi)r_i)(1+\phi)}$,
$\hat{\theta}^\star = \frac{(1+\phi r_a+(1-\phi)r_i)v+(2\phi-1)\phi(1+r_a)q_E}{2\phi(1+\phi)(1+r_a)q_E}$,
$\Pi^\star_I = \frac{(1+\phi r_a+(1-\phi)r_i)^2v^2+2(2\phi-1)\phi(1+\phi r_a+(1-\phi)r_i)(1+r_a)q_E v+(5-4\phi)\phi^2(1+r_a)^2{q_E}^2}{4(1+\phi)\phi(1+\phi r_a+(1-\phi)r_i)(1+r_a)q_E}$,
$\Pi^\star_E = \frac{[3(1+r_a)\phi q_E-(1+\phi r_a+(1-\phi)r_i)v]^2}{4(1+\phi)^2(1+r_a)(1+\phi r_a+(1-\phi)r_i)q_E}$.

The first order derivatives of profits w.r.t. regret are:

$\frac{\partial\Pi^\star_I}{\partial r_a} = \frac{[(5-4\phi)\phi^2(1+r_a)^2{q_E}^2-(1+\phi r_a+(1-\phi)r_i)^2v^2]}{4(1+\phi)\phi(1+\phi r_a+(1-\phi)r_i)^2(1+r_a)^2q_E}$, $\frac{\partial\Pi^\star_I}{\partial r_i} = \frac{(1-\phi)[(1+\phi r_a+(1-\phi)r_i)^2v^2-(5-4\phi)\phi^2(1+r_a)^2{q_E}^2]}{4(1+\phi)\phi(1+\phi r_a+(1-\phi)r_i)^2(1+r_a)q_E}$,
$\frac{\partial\Pi^\star_E}{\partial r_a} = \frac{(1-\phi)(1+r_i)(9(1+r_a)^2\phi^2{q_E}^2-(1+\phi r_a+(1-\phi)r_i)^2v^2)}{4(1+\phi)^2(1+r_a)^2(1+\phi r_a+(1-\phi)r_i)^2q_E}$, $\frac{\partial\Pi^\star_E}{\partial r_i} = -\frac{(1-\phi)(1+r_a)(9(1+r_a)^2\phi^2{q_E}^2-(1+\phi r_a+(1-\phi)r_i)^2v^2)}{4(1+\phi)^2(1+r_a)^2(1+\phi r_a+(1-\phi)r_i)^2q_E}$.

Obviously, $\frac{\partial\Pi^\star_I}{\partial r_a} = -\frac{\partial\Pi^\star_I}{\partial r_i} * \frac{1}{(1-\phi)(1+r_a)}$. Therefore, $|\frac{\partial\Pi^\star_I}{\partial r_a}| \geq |\frac{\partial\Pi^\star_I}{\partial r_i}|$ if and only if $(1-\phi)(1+r_a) \leq 1 \Rightarrow r_a \leq \frac{\phi}{1-\phi}$. I can easily obtain that $\frac{\partial\Pi^\star_E}{\partial r_a} > 0$ and $\frac{\partial\Pi^\star_E}{\partial r_i} < 0$. Besides, $|\frac{\partial\Pi^\star_E}{\partial r_a}| \geq |\frac{\partial\Pi^\star_E}{\partial r_i}|$ if and only if $r_i \geq r_a$. ■

B.5 Proof of the incumbent's Minor Upgrade

Proof of Proposition 2.7: Let Δq denote $(q_E - q_I)$. Following the same steps in previous Claims, the incumbent's profit is:

(a) When $r_a > r_i = 0$: $\Pi^\star_I = \frac{(1+r_a\phi)^2v^2+(5-4\phi)(1+r_a)^2\phi^2\Delta q^2+2(2\phi-1)(1+r_a)(1+r_a\phi)\phi\Delta q v}{4(1+\phi)(1+r_a)(1+r_a\phi)\phi\Delta q}$. Then

$\frac{\partial \Pi_I^\star}{\partial r_a} > 0 (< 0)$ iff $\sqrt{5-4\phi}(1+r_a)\phi\Delta q - (1+\phi r_a)v > 0 (< 0)$. Also, $\frac{\partial \Pi_I^\star}{\partial q_I} > 0 (< 0)$ iff $\sqrt{5-4\phi}(1+r_a)\phi\Delta q - (1+\phi r_a)v < 0 (> 0)$. Note that anticipated action regret and free upgrades of q_I have opposite effects on the incumbent's profit.

(b) When $r_i > r_a = 0$: $\Pi_I^\star = \frac{[1+(1-\phi)r_i]^2 v^2 + 2(2\phi-1)[1+(1-\phi)r_i]\phi\Delta q v + (5-4\phi)\phi^2\Delta q^2}{4[1+(1-\phi)r_i](1+\phi)\phi\Delta q}$. Then $\frac{\partial \Pi_I^\star}{\partial r_i} > 0 (< 0)$ iff $[1+(1-\phi)r_i]v - \sqrt{5-4\phi}\phi\Delta q > 0 (< 0)$. Also, $\frac{\partial \Pi_I^\star}{\partial q_I} > 0 (< 0)$ iff $[1+(1-\phi)r_i]v - \sqrt{5-4\phi}\phi\Delta q > 0 (< 0)$. Anticipated inaction regret and free upgrades have the same effect on the incumbent's profit. It is easy to see that the effect of q_I on the entrant's profit is the same as the one of inaction regret. ■

B.6 Proof of the Longer Durability

Proof of Proposition 2.8:

(i) When consumers anticipate action regret:

$Eu_{I1} = kv - p_{I1} - \phi r_a[(k-1)\theta q_E - p_{E2} - v + p_{I1}]$,

$u_{I2} = (k-1)v - p_{I2}$, $Eu_{E2} = (k-1)(v + \phi\theta q_E) - p_{E2}$;

In equilibrium, prices, demand and profits are:

$p_{I1}^\star = \frac{(2-\phi)\phi(1+r_a)(k-1)q_E + \phi(1+r_a\phi)v}{(1+\phi)(1+r_a\phi)}$, $p_{E2}^\star = p_{I2}^\star = \frac{3(1+r_a)\phi(k-1)q_E - (1+r_a\phi)v}{2(1+r_a\phi)(1+\phi)}$,

$\hat{\theta}^\star = \frac{(1+r_a\phi)v + (2\phi-1)(1+r_a)\phi(k-1)q_E}{2(1+\phi)(1+r_a)\phi(k-1)q_E}$,

$\Pi_I^\star = \frac{(1+r_a\phi)^2v^2 + (5-4\phi)(1+r_a)^2\phi^2(k-1)^2{q_E}^2 + 2(2\phi-1)(1+r_a)(1+r_a\phi)\phi(k-1)q_E v}{4(1+\phi)(1+r_a)(1+r_a\phi)\phi(k-1)q_E}$,

$\Pi_E^\star = \frac{[3(1+r_a)\phi(k-1)q_E - (1+r_a\phi)v]^2}{4(1+\phi)^2(1+r_a)(1+r_a\phi)(k-1)q_E}$.

Under Assumption 2.1, the condition such that $\frac{\partial \Pi_I^\star}{\partial r_a} \geq 0$ and $\frac{\partial \Pi_I^\star}{\partial k} \geq 0$ is:

$$\sqrt{5-4\phi}(1+r_a)\phi(k-1)q_E - (1+r_a\phi) > 0.$$

Therefore, the effect of a longer duration of the product is the same as that of the anticipated action regret.

(ii) When consumers anticipate inaction regret:

$u_{I1} = kv - p_{I1}$, $u_{I2} = (k-1)v - p_{I2}$,

$Eu_{E2} = (k-1)(v + \phi\theta q_E) - p_{E2} - (1-\phi)r_i(v - p_{I1} + p_{E2})$.

In equilibrium, prices, demand and profits are:

$p_{I1}^{\star} = \frac{(2-\phi)\phi(k-1)q_E+\phi[1+(1-\phi)r_i]v}{(1+\phi)[1+(1-\phi)r_i]}$, $p_{E2}^{\star} = p_{I2}^{\star} = \frac{3\phi(k-1)q_E-[1+(1-\phi)r_i]v}{2[1+(1-\phi)r_i](1+\phi)}$,

$\hat{\theta}^{\star} = \frac{[1+(1-\phi)r_i]v+(2\phi-1)\phi(k-1)q_E}{2(1+\phi)\phi(k-1)q_E}$,

$\Pi_I^{\star} = \frac{[1+(1-\phi)r_i]^2v^2+2(2\phi-1)[1+(1-\phi)r_i]\phi v(k-1)q_E+(5-4\phi)\phi^2(k-1)^2{q_E}^2}{4[1+(1-\phi)r_i](1+\phi)\phi(k-1)q_E}$,

$\Pi_E^{\star} = \frac{(3\phi(k-1)q_E-[1+(1-\phi)r_i]v)^2}{4(1+\phi)^2[1+(1-\phi)r_i](k-1)q_E}$.

Given Assumption 2.1 and Assumption 4, the conditions such that $\frac{\partial \Pi_I}{\partial r_i} \leq 0$ and $\frac{\partial \Pi_I}{\partial k} \geq 0$ are the same, which is: $\sqrt{5-4\phi}\phi(k-1)q_E - (1-\phi)r_i - 1 \geq 0$. Note that, the effect of a longer duration of the product is opposite to that of the anticipated inaction regret. ■