# WORKFORCE MANAGEMENT IN THE NEW ECONOMY

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WORKFORCE MANAGEMENT IN THE NEW ECONOMY

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My dissertation examines issues related to the management of workers under new technological advances or regulations. The dissertation is divided into three parts.

The first part focuses on dispute management in online gig platforms. Traditionally, disputes between a worker (freelancer) and a client on an online gig platform are mediated by the platform itself, which can be viewed as unhelpful or biased. However, emerging platforms promise to resolve disputes with a novel tribunal system that relegates resolution to individual platform users through a voting mechanism. To assess whether emerging platforms have an advantage over traditional online labor platforms, we examine the dispute resolution models used by both centralized and decentralized platforms using a game theoretic model.

The second part of the dissertation shifts the focus to workers in the service industry who tend to have varying work schedules from week to week. Such unpredictable work schedules can be detrimental to their welfare. The predictive scheduling law, implemented in some areas, serves to protect these workers by requiring firms to schedule work in advance or compensate workers if they do not. However, opponents of the law argue that such intervention may be harmful to both firms and workers. To analyze the law's effect, we build a game theoretic model and present empirical evidence using data from the statewide implementation of a predictive scheduling law in Oregon.

In the third part of the dissertation, we again focus on workers on an online platform. The rise of the gig economy has led regulators and the general public to be concerned about the welfare of freelancers who often do not receive employment benefits but have the flexibility to dictate their work pace. As such, there are calls for labor laws to be put in place for gig workers and for platforms to employ freelancers as employees. Moreover, the issue of whether to hire freelancers or employees has created a divide among gig platforms. To study the value of having freelancers over employees in an online platform, we conduct a field experiment with a major food delivery platform. Our study yields insights on how platform should manage freelancers and employees.

Through these three parts, my dissertation delves into the intricacies of worker management under evolving technological landscapes and regulatory frameworks, contributing to the broader understanding of these complex issues.

## BIOGRAPHICAL SKETCH

Wee Kiat Lee was born in Singapore, a tropical island in Southeast Asia. Like any other Singaporean men, he fulfilled his national duty by serving almost two years with the Republic of Singapore Air Force. During this period, beside protecting the skies, he found himself contemplating the broader aspects of life and eventually decided to pursue a Bachelor's degree in Civil Engineering, specializing in Offshore Engineering, at the National University of Singapore.

After graduating, Wee Kiat embarked on a career in the maritime industry, working as a civil engineer. His dedication and passion for life-long learning led him to take on the challenge of simultaneously studying and working full-time. In this pursuit, he obtained a Master's degree in Financial Engineering from the National University of Singapore.

While progressing in his career, Wee Kiat gradually transitioned into project management roles within the construction of sea ports. This exposed him to the fascinating realm of port operations, which captured his keen interest. It spurred him to make the decision to pursue a doctoral degree in operations management, even though he was already married and was expecting a child.

Undeniably, Wee Kiat's pursuit of a doctoral degree was an arduous path, further complicated by the arrival of the unprecedented COVID-19 pandemic, which severely limited available childcare options. Undeterred by these challenges, Wee Kiat persevered, and received his second Master's degree and his Ph.D. in Operations, Technology, and Information Management from the SC Johnson College of Business at Cornell University.

To my family and friends

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# TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

CHAPTER 1

# SHOULD GIG PLATFORMS DECENTRALIZE DISPUTE RESOLUTION?

## 1.1 Introduction

Online labor platforms have experienced tremendous growth over the years. According to a study by Katz and Krueger (2019), online labor platforms account for more than 90% of net employment growth in the United States between 2005 and 2015. These platforms host a wide range of tasks, such as website and graphic design (e.g., Upwork and Freelancer.com), programming (e.g., PeoplePerHour), home services (e.g., TaskRabbit), and personal assistance for daily or ad-hoc needs (e.g., Fancy Hands). These online labor platforms are part of the broader "gig economy", where they leverage the expertise of freelancers and provide them with flexible work opportunities. Freelancers can often work remotely and on their own schedule, increasing flexibility for businesses and facilitating connections between suitable tasks and available freelancers. The recent COVID-19 pandemic has further amplified the use of online labor platforms, resulting in a 47% increase in employers hiring freelancers from these platforms as they adapt to remote work and seek more flexible workers to navigate evolving business landscapes (Upwork 2020).

However, despite the convenience of connecting clients with freelancers, online labor platforms are not without drawbacks. Concerns often arise regarding the quality of freelancers' work, as their skill levels may be lower compared to professional employees, and many platforms lack stringent screening processes to ensure quality. To address this concern, online labor platforms often allow clients to reject payment to freelancers even after the work is completed

(Aloisi 2016). However, this leads to a potential contention for payment disputes. Moreover, the lack of face-to-face interaction can result in more disagreements over the quality of work delivered. As a result, disputes can be a common occurrence on online labor platforms (DeVault et al. 2019). Traditionally, the resolution of disputes has relied on the platform acting as an arbitrator (Aloisi 2016). Although the platform retains more decision-making power in this case, its arbitration may be biased towards a particular side due to a conflict of interest. We term this dispute resolution method as the "centralized dispute system".

Due to concerns about the centralized nature of traditional platforms' dispute arbitration, emerging platform such as LibertyLance and Ethearnal are introducing a novel tribunal system to ensure fairer dispute settlements. Under this system, members of the platforms are allowed to participate in the tribunal to assess and vote on dispute cases between clients and freelancers. When a dispute occurs, a tribunal is formed and the side with the majority vote wins the case. This way, the platform outsources dispute resolution to the tribunal and crowdsources justice from its diverse members. To implement the tribunal system, these emerging platforms have developed a self-funded mechanism where each voter is required to deposit a certain amount of money to participate in the tribunal. The total deposit forms a reward pool, which is then distributed to the winning side of voters based on the majority rule. Consequently, the voters who vote with the majority will earn a monetary reward, while the voters who vote with the minority will lose their stake to the winning side. We term this dispute resolution method as the "decentralized dispute system".

The decentralized dispute system offers several advantages. First, it is more cost-effective as the platform outsources dispute resolution to the tribunal, freeing up resources that would otherwise be invested in resolving disputes (CryptoTask 2022). Second, by crowdsourcing dispute resolution to the public, the dispute system becomes more scalable, as highlighted in an interview with the CEO of an emerging platform (Rasheed 2021). This means that the system can handle a potential increase in disputes from an expanding user base. Third, the tribunal system can resolve disputes in a more timely manner if the voting process is limited to a short time window, typically 24 hours, compared to traditional platforms that can take several weeks (Hyve 2023). In addition to these benefits, the emerging platforms also believe that the decentralized dispute system is fairer since disputes are resolved by a group of users rather than a single entity (Ethearnal 2021). Furthermore, these platforms randomly assign voters to individual dispute cases, so that the platform users do not know apriori which dispute case they will be assigned to. This helps minimize the possibility of collusion and ensure a fair voting outcome.

However, the decentralized dispute mechanism is not without risks. The monetary reward introduced by the self-funded mechanism may potentially incentivize the voters to vote strategically in order to win rather than achieve justice.. Thus, it is not clear whether the existence of a monetary incentive can still elicit a fair judgment from the voters, and whether the voters' strategic voting decisions can still effectively incentivize quality improvement from the freelancers. Motivated by the recent industry practice, we aim to answer the following research questions in this paper. First, in light of the above concern of strategic voting, can the decentralized dispute system achieve justice in dispute resolution, and under what conditions? Second, when can the decentralized dispute system be more profitable for the platform? Third, does the decentralized dispute system benefit the platform without hurting the social welfare?

We model a platform that intermediates the transaction between a client and a freelancer. The client offers a contract price to the freelancer and the freelancer chooses the quality of work. Upon receiving the work, the client has the right to reject payment to the freelancer, in which case the freelancer can initiate a dispute by paying the dispute fee to the platform. If the centralized dispute system is adopted, the dispute outcome will be determined by the platform. On the other hand, if the decentralized dispute system is adopted, a tribunal consisting of independent platform users will be formed to vote on the dispute case. Each member of the tribunal deposits a participation fee and those who vote for the winning side will share the total deposit. The voters can have different but correlated evaluations of the freelancer's work quality and can vote strategically by taking into account the chance of winning, for which they need to form beliefs about the other voters' votes without any communication among themselves. This makes the tribunal's voting game a coordination game, which we model using the global games framework (Carlsson and van Damme 1993 and Morris and Shin 1998). If the freelancer wins the dispute so that the client has to pay the freelancer, or if the client accepts the freelancer's work in the first place, the platform earns a percentage commission from the contract price. Thus, the platform can earn revenues from two sources: 1) extracting commissions, and 2) charging dispute fees.

First, by examining the decentralized dispute system, we find that despite the voters' strategic motive to coordinate with each other, *the tribunal's voting mechanism can ensure a just dispute resolution outcome if the degree of subjectivity in the voters' judgments is sufficiently high*. In this case, the voters can coordinate on a fair equilibrium where they evaluate the freelancer's work quality according to a publicly recognized industry standard. However, if the degree of subjectivity is low, the voters' judgments are likely to be similar, resulting in a situation where they follow each others' decisions rather than adhering to a fair industry standard. This not only makes an unfair equilibrium possible, but also creates multiple equilibria, resulting in a coordination failure in the voting game. Therefore, the tribunal's ability to elicit diverse opinions from its members is critical for the decentralized dispute system to function effectively, and the platform should be cautious about any policy that may homogenize voters' judgments. Moreover, achieving the fair equilibrium in the tribunal indicates that the decentralized dispute system can effectively eliminate the platform's decision-making bias that arises under the centralized dispute system. Because the platform will earn the commission if the freelancer wins the dispute, such a conflict of interest induces the platform to set a lower quality standard to rule in favor of the freelancer. By eliminating this bias, the decentralized dispute system requires a more stringent quality standard for the freelancer.

Next, by comparing the platform's equilibrium utilities under the two dispute systems, we find that *the decentralized dispute system is more profitable as long as the freelancer's skill level is sufficiently high*. The higher quality standard under the decentralized dispute system has different implications for different types of freelancers. If the freelancer is sufficiently skilled to meet the higher quality standard, the client will be willing to offer a higher contract price and the platform will be able to extract more surplus from the transaction. However, if the freelancer's skill level is insufficient, the higher quality standard will make it even more difficult for the freelancer to participate. In this case, the centralized dispute system enables the platform to adapt to a lower quality standard and allow more lower-skilled freelancers to participate. Therefore, in order to reap any benefit from the decentralized dispute system, platforms should ensure the skill level of the freelancer pool, which can be achieved by using certification or providing training programs.

Finally, while the decentralized dispute system strengthens the freelancer's incentive to improve quality by eliminating the platform's decision-making bias, *the induced equilibrium quality level is guaranteed to be more socially optimal only if the voters are not too strict*. If the tribunal's judging criterion is overly stringent, the freelancer will be forced to provide a quality level that is too high compared to the socially optimal level. Therefore, educating the general public to form a proper standard can ensure that the decentralized dispute system benefits the platform while inducing a more socially optimal equilibrium outcome, achieving a win-win solution for gig platforms and policy makers.

## 1.2 Literature Review

Our paper is related to three streams of literature: 1) voting games, 2) platform operations, and 3) dispute management. First, to model the voting decisions of the tribunal members, we utilize the global games framework, which is pioneered by Carlsson and van Damme (1993) and Morris and Shin (1998). "Global games" is a class of games where each player observes a private but correlated signal of the fundamental state and has to account for the other players' beliefs when deciding their own action. This framework has been used in the economics literature to capture the strategic interactions between decisions makers in voting game settings and has recently been used by operations management researchers. For example, Wang et al. (2021) study the strategic interactions between firms in the adoption of green technology. By using the global games framework, each firm observes a private but correlated benefit of the new green technology when making the adoption decision, and their payoffs are influenced by the other firms' decisions as the regulator will make green technology adoption mandatory based on the proportion of firms who voluntarily adopt it. In a similar spirit, we apply the global games framework to study the strategic interactions between the tribunal members under the decentralized dispute system. In our model, each voter observes a private but correlated sentiment of the freelancer's work. Since a voter's payoff is influenced by whether his vote belongs to the majority of votes, he needs to reason on the other voters' perception of the freelancer's work in his own decision-making process. In addition, because voting is a form of group-based decision-making, our paper is related to other settings that involve group-based decision-making, such as crowdfunding (e.g., Xu and Zhang 2018, Chakraborty and Swinney 2019, Belavina et al. 2020, Chakraborty et al. 2023), information acquisition (e.g., Marinesi and Girotra 2013, Tsoukalas and Falk 2020), and team coordination (e.g., Dawande et al. 2019, Roels and Corbett 2021).

The operations management literature has so far studied several issues in platform operations, such as wage schemes (e.g., Taylor 2018, Bai et al. 2019, Hu and Zhou 2020), surge pricing (e.g., Cachon et al. 2017, Guda and Subramanian 2019, Hu et al. 2022), platform competition (e.g., Bernstein et al. 2021, Chen et al. 2022a), and labor welfare (e.g., Benjaafar et al. 2019, Benjaafar et al. 2022). Papers in this stream have typically considered settings where the platform sets the wages for the freelancers. Our setting differs in that a freelancer's wage is determined by a contracting process between the client and the freelancer, which is typical for online labor platforms. While contracting has been extensively studied in supply chain settings (see Elmaghraby 2000 for a review), our platform setting is distinguished by the unique feature that the contract between the client and the freelancer is mediated by the platform. Moreover, because the contracts on online labor platforms are signed between individual users on small-scale short-term projects, they are less formal in nature compared to supply chain contracts, leading to a higher likelihood of user disputes.

Dispute management in informal contracting settings has recently gained interest in operations management research. One such study by Papanastasiou et al. (2022) considers an e-commerce seller's dispute over a customer review. They examine when a semi-decentralized dispute system that allows the seller to remove a customer's review subject to potential checks by the platform can be more efficient than the centralized dispute system where the platform decides whether a customer review should be removed. Our study differs in two ways. First, we study disputes that arise from payment rejections, rather than from untruthful customer reviews. As a result, the reasons for initiating a dispute and the underlying economic dynamics are different. Second, we study a fully decentralized mechanism of dispute resolution, where independent platform users are involved to vote on a dispute case, and the platform fully relegates the authority to arbitrate dispute cases. Another study by Kwan et al. (2023) considers a crowdjudging-based dispute system, which is more similar to ours. They use a dataset from Taobao to empirically demonstrate that the bias in crowdjudging tends to decrease as jurors gain experience. Our paper, on the other hand, considers a different crowdjudging mechanism where voters can earn a monetary payoff based on the voting outcome and hence can act strategically. We provide the analytical insight that ensuring the diversity of voter opinions plays a critical role in achieving justice of the voting outcome. In addition, our paper compares the performance of the decentralized dispute system (judged by the public) with the centralized dispute system (judged by the platform) and prescribes when the decentralized dispute system should be preferred by the platform and the social planner.

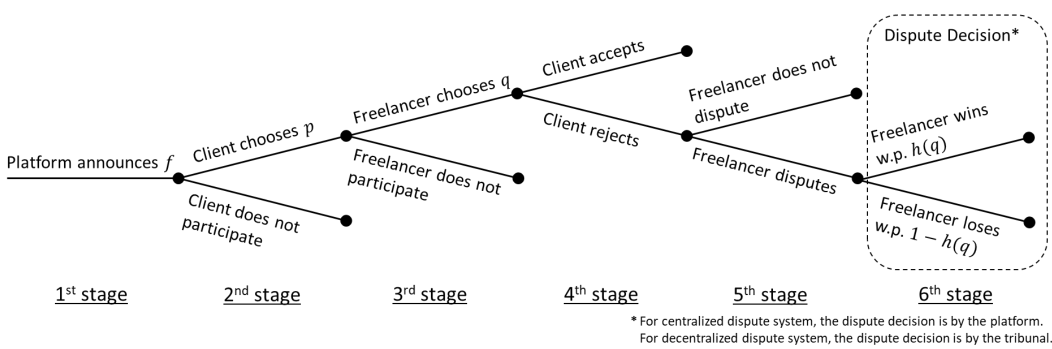
## 1.3 Model Setup

We consider a platform that serves as an intermediary between a client (referred to as "her") and a freelancer (referred to as "him"). The *platform*'s revenue consists of two components. First, the platform extracts a commission equal to $\gamma$ fraction of the contract price. The commission is paid by the freelancer, who is the party receiving the payment. We assume that the commission rate is exogenously given by the industry norm, whereas the contract price is endogenously determined by the contracting process between the client and the freelancer. The commission rate of online labor platforms typically falls in a narrow range of 10–20%. For example, the commission rate is 10% for Freelancer.com, 15% for TaskRabbit, and 20% for PeoplePerHour and Upwork. Second, the platform charges a dispute fee $f \geq 0$, which is paid by the freelancer if he decides to initiate a dispute. The dispute fee is endogenously chosen by the platform, and is non-refundable regardless of the dispute outcome (e.g., PeoplePerHour). The dispute fee charged by online labor platforms varies considerably. For example, PeoplePerHour charges either $8 or 10% of the contract price, whichever is higher, whereas Upwork charges a flat fee of $200 regardless of the contract price. Nevertheless, the magnitude of the dispute fee is comparable to the commission fee, making it a significant source of revenue for these platforms. In our main model, we assume the platform charges the dispute fee only to the freelancer, who is the party initiating the dispute. In Section 1.9.3, we consider an alternative setting where the platform charges the dispute fee to both the client and the freelancer.

The *freelancer* chooses the work quality $q \geq 0$ and faces an effort cost $\alpha q^2$ which is a convexly increasing function of $q$, where $\alpha$ represents the efficiency of the freelancer (Ha et al. 2016). A freelancer with a smaller $\alpha$ can achieve the same quality $q$ at a lower cost, hence his skill level is higher (Banker et al. 1998). For example, an experienced graphic designer can easily design a logo due to familiarity with professional software such as Adobe Photoshop, whereas a less experienced designer may need to invest time in learning the software before starting the project, resulting in increased costs. We assume that $\alpha$ is public information since it is common practice for online labor platforms to have a reputation system for the users, and a freelancer's skill level can be inferred from his rating and historical reviews (Jin et al. 2022). Note that because we consider a single freelancer in our main model, $\alpha$ can be interpreted as the skill level of the freelancer pool. In Section 1.9.7, we consider a model extension where the freelancer pool can have heterogeneous skill levels. Moreover, we assume that the work can be completed with certainty. In Section 1.9.4, we consider a model extension where the freelancer faces the risk of task failure.

The *client*'s valuation of the work is assumed to be equivalent to the work quality $q$. This assumption is made without loss of generality as our results remain valid even if the client's valuation can be different from $q$ but follows an increasing linear function of $q$. When the client offers a contract, she chooses the contract price $p \geq 0$. Quality is not contractible because it is uncommon for gig work to have a quality expectation formally specified in a contract. Shevchuk and Strebkov (2018) find that only 11% of the tasks rely on formal contracts, while the majority rely on verbal or informal correspondence. Even if a formal contract is created, specifying a quality standard can be challenging as textual descriptions can be ambiguous and task objectives are subjective in nature. Since a quality standard is not specified, the client can reject the freelancer's work and refuse to pay, in which case the freelancer has the option to file a dispute. The client obtains the valuation of work regardless of whether she rejects it or not, to reflect the nature of gig work that it typically involves providing a service which cannot be returned like a physical product. In our model, payment rejection and dispute apply to the entire contract price, corresponding to a fixed-price contract where disputes can only be filed on the entire contract. It is worth mentioning that online labor markets use fixed-price contracts for the majority of tasks (Liang et al. 2016), as they are short-term small-scale projects. Some platforms (e.g., Upwork and Freelancer.com) offer the option of milestone payments for larger-scale projects, which allow disputes on particular milestones. However, each milestone payment can be treated as a separate fixed-price contract, and our insights are also applicable.

Figure 1.1: Sequence of events.




The sequence of events is illustrated in Figure 1.1. The game consists of six decision-making stages, beginning with the platform choosing the dispute fee $f$ (Stage 1). The client then chooses the contract price $p$ to offer to the freelancer

(Stage 2), and the freelancer subsequently chooses the quality level $q$ (Stage 3). After completing the task, the client decides whether to accept or reject the freelancer's work (Stage 4). If the client accepts the freelancer's work, the transaction concludes, and the platform receives the commission $\gamma p$, while the freelancer receives the payment $(1-\gamma)p$. If the client rejects the work, the freelancer decides whether to initiate a dispute by paying the dispute fee $f$ (Stage 5). Finally, if the freelancer chooses to initiate a dispute, a dispute resolution process is invoked (Stage 6). If the freelancer wins the dispute, he receives the payment and the platform receives the commission. The platform, the client, and the freelancer are all forward-looking decision-makers.

We consider two types of dispute systems: the centralized and decentralized dispute systems. The difference between the two systems lies only in Stage 6 of the sequence of events. Specifically, under the centralized dispute system (Section 1.4), the platform is responsible for carrying out the dispute resolution, while under the decentralized dispute system (Section 1.5), a tribunal is responsible. We describe the models of the dispute resolution processes for both systems in subsequent sections, and Appendix A.1 provides examples of gig platforms' dispute policies for each system. Since evaluations of gig work tend to be subjective, an external evaluator (such as the platform or the voters in a tribunal) may form a different evaluation of the freelancer's work than the client. In addition, the true quality of work is only known to the client and the freelancer (i.e., the contracting parties), but not observable to an external evaluator (Baker et al. 1994, Levin 2003). As we will show, the outcome of dispute resolution yields the freelancer a probability of winning the dispute, which we denote as $h(q)$. We use superscripts of $*$ and $+$ to differentiate between the equilibria of the centralized and decentralized dispute systems, respectively. The proofs of results for the main model are presented in Appendix A.2 to A.4.

## 1.4 Centralized Dispute System

In this section, we study the centralized dispute system, where disputes are resolved by the platform. In Section 1.4.1, we first delve into the platform's decision-making process of dispute resolution. Then, building on the platform's dispute decision, we proceed to analyze the overall game between the client, the freelancer, and the platform in Section 1.4.2.

### 1.4.1 Platform's Dispute Decision

We first model and analyze the subgame of the platform's dispute resolution given that a dispute has been initiated. In reality, a platform would make such a decision by evaluating whether the freelancer's work quality is sufficiently high to justify payment. To mimic this decision-making process, we assume that the platform chooses a quality threshold $k$ and compares the evaluated quality of the freelancer's work to this threshold. The platform's quality threshold is not announced upfront but chosen when a dispute has occurred, to reflect the reality that it could be difficult for the platform to credibly commit to a quality evaluation criterion. However, the platform's dispute arbitration is binding. In Section 1.9.1, we consider a model extension where the platform's dispute arbitration is non-binding and the users can appeal the platform's dispute decision, in which case a third-party arbitration will be involved to make a binding decision.

The outcome of dispute resolution can be influenced by the subjective judgment of the evaluator (Taylor and Yildirim 2011, Deb et al. 2016), who is typically a member of the platform's dispute team. For example, even if two logos are designed by the same freelancer with the same amount of effort, they may receive different evaluations from the evaluator due to the evaluator's personal aesthetic preferences. Since the exact preference of the evaluator is unknown until the evaluation is made, there is variability in the evaluated quality. We assume that the evaluator's subjective judgment causes the evaluated quality to be a random variable around the freelancer's true quality $q$. The platform's evaluated quality is represented by the evaluator's judgment, given by a random variable $x = q + \sigma\epsilon$, where $\epsilon$ is uniformly distributed over $[-1, 1]$ and $\sigma$ is a scaling factor that measures the *degree of subjectivity* in the platform's evaluation. Consequently, the platform will rule in favor of the freelancer if $x \geq k$ and in favor of the client if $x < k$. Let $h(q, k)$ denote the resulting probability for the freelancer to win the dispute following this decision-making rule.

Moreover, the platform's dispute decision can be affected by its concern about how closely its judgment aligns with the industry norm. A decision that deviates significantly from the industry norm may invite heavy criticism and damage the platform's reputation, which can, in turn, negatively affect its future revenue. For example, setting a standard that is too high may cause the platform to lose freelancers, while setting it too low may discourage client participation. To account for this, we introduce a disutility term that represents the platform's cost of deviating from the industry norm. Specifically, we model this term as $-\theta(k - y)^2$, which is a quadratic function of the distance between the platform's threshold $k$ and the industry standard $y$. $y$ represents the quality standard expected by the general public and serves as an anchoring point for a "fair" judgment in our model (Chen 2022). In other words, a quality evaluation criterion is deemed fair if it conforms to the industry norm. It is easy to see that a higher value of $y$ indicates that the public holds a stricter standard, which means that even under fair judgment, the freelancer would have to put in more effort. $\theta > 0$ represents the degree of penalization when the platform deviates from the industry norm. The quadratic term captures the two-sided impact that the platform's long-term reputation can be negatively affected if it unfairly rules in favor of either side of the market (Tsoukalas and Falk 2020).

Therefore, the platform's utility comprises two components:

$$\Pi(k, f) = [h(q, k)(\gamma p + f) + (1 - h(q, k))f] - \theta(k - y)^2. \tag{1.1}$$

As shown by Equation (1.1), the first component is the monetary payoff from earning commissions and dispute fees, and the second component is the disutility if the platform deviates from the industry norm in its dispute resolution. Lemma 1.1 characterizes the platform's equilibrium quality threshold and the resulting winning probability of the freelancer for the dispute resolution subgame.

**Lemma 1.1** *(i) Under the centralized dispute system, the platform's quality threshold is* $k^* = y - \frac{\gamma p}{4\sigma\theta}$.

*(ii) The probability of the freelancer winning the dispute is*

$$h^*(q) = \begin{cases} 0 & \textit{if } q \leq k^* - \sigma, \\ \frac{q-y+\sigma}{2\sigma} + \frac{\gamma p}{8\theta\sigma^2} & \textit{if } k^* - \sigma < q < k^* + \sigma, \\ 1 & \textit{if } q \geq k^* + \sigma, \end{cases}$$

*which is increasing in $q$, and decreasing in $\theta$ and $y$.*

Lemma 1.1 shows that the platform's quality threshold $k^*$ is always lower than the industry standard $y$, and is dependent on the magnitude of the commission fee $\gamma p$. If dispute occurs and the platform rules in favor of the freelancer, it is able to earn the commission fee in addition to the dispute fee. Thus, the platform intentionally sets a lower quality threshold than the industry standard (i.e., $k^* \leq y$) to increase the winning probability of the freelancer. As a result, the probability of the freelancer winning the dispute comprises two components: 1) the probability that the platform's evaluated quality is above the industry standard $y$ (i.e., $\frac{q-y+\sigma}{2\sigma}$), and 2) a positive *bias term* that increases his chance of winning the dispute (i.e., $\frac{\gamma p}{8\theta\sigma^2}$). Furthermore, the bias term increases if the commission fee is higher, and decreases if the degree of penalization $\theta$ is higher.

Thus, serving as both the intermediary of transactions and the arbitrator of disputes, centralized dispute resolution will inevitably lead to a conflict of interest in the platform's decision-making process. The platform's inclination to let the freelancer win has been observed by the clients who have gone through the dispute process (Tzezana 2015, Chen 2017, Chris 2021). These clients warn that arbitration rarely rules in favor of the client. Moreover, they complain that the unfair dispute resolution gives rise to freelancers relying on dispute to earn their profit, instead of putting in effort to improve their work quality. As our model highlights, such an issue is rooted in the platform's decision-making bias caused by the centralized mechanism of dispute resolution.

### 1.4.2 Contracting Equilibrium Under Centralized Dispute System

Given the equilibrium of the dispute resolution subgame obtained from Section 1.4.1, we continue the backward induction process of the overall game and solve for the contracting equilibrium between the client and the freelancer as well as the platform's equilibrium dispute fee. Using the equilibrium winning probability of the freelancer if dispute occurs, $h^*(q)$, we can express the utilities of all decision-makers as follows. In particular, under the centralized dispute system, if both the client and the freelancer participate, the freelancer's utility is given by

$$U_f(q) = \begin{cases} -\alpha q^2 + h^*(q)(1-\gamma)p - f & \text{if client rejects and freelancer disputes,} \\ -\alpha q^2 & \text{if client rejects and freelancer does not dispute,} \\ -\alpha q^2 + (1-\gamma)p & \text{if client accepts,} \end{cases} \tag{1.2}$$

and the client's utility is given by

$$U_c(p) = \begin{cases} q - h^*(q)p & \text{if client rejects and freelancer disputes,} \\ q & \text{if client rejects and freelancer does not dispute,} \\ q - p & \text{if client accepts.} \end{cases} \tag{1.3}$$

As the client is forward-looking, her decision to accept or reject the freelancer's work takes into account the platform's dispute judging criterion, which results in the client rejecting the freelancer's work in equilibrium if and only if the freelancer's quality is below a threshold.[1] Similarly, given that the client has rejected

[1]When a platform user obtains the same utility from an option that does not lead to a dispute and another option that leads to a dispute, we use the tie-breaking rule that the platform users

the freelancer's work, the freelancer's decision to initiate a dispute or not also takes into account the platform's dispute judging criterion, which results in him initiating a dispute if and only if his quality is above a threshold. Finally, the platform's utility is given by

$$\Pi(f) = \begin{cases} [h^*(q)(\gamma p + f) + (1 - h^*(q))f] - \theta(k^* - y)^2 & \text{if client rejects and freelancer disputes,} \\ 0 & \text{if client rejects and freelancer does not dispute,} \\ \gamma p & \text{if client accepts, .} \end{cases} \tag{1.4}$$

Proposition 1.1 characterizes the equilibrium under the centralized dispute system.

**Proposition 1.1** *(i) Under the centralized dispute system, there exist two thresholds, $\bar{\alpha}_c$ and $\underline{\alpha}_c$ (where $\bar{\alpha}_c \geq \underline{\alpha}_c$), such that contracting occurs if and only if $\alpha \leq \bar{\alpha}_c$, and given that contracting occurs, dispute occurs if $\underline{\alpha}_c < \alpha \leq \bar{\alpha}_c$ and does not occur if $\alpha \leq \underline{\alpha}_c$.*

*(ii) If $\alpha \leq \underline{\alpha}_c$, the platform's dispute fee is $f^* = \frac{4(1-\gamma)\sigma\theta(y+\sigma)}{\gamma+4\sigma\theta}$, the client's contract price is $p^* = \frac{4\sigma\theta(y+\sigma)}{\gamma+4\sigma\theta}$, and the freelancer's quality level is $q^* = \frac{4\sigma\theta(y+\sigma)}{\gamma+4\sigma\theta}$. In this case, the client accepts the freelancer's work. Moreover, the platform's equilibrium utility is $\Pi^* = \gamma p^*$.*

*(iii) If $\underline{\alpha}_c < \alpha \leq \bar{\alpha}_c$, the platform's dispute fee is $f^* = \frac{(1-\gamma)^2\theta(2\alpha(y-\sigma)+(1-\gamma))(2\alpha(\gamma-\theta(y-\sigma))+(1-\gamma)\theta)}{4\alpha(\gamma\alpha+(1-\gamma)\theta)^2}$, the client's contract price is $p^* = \frac{2\sigma\theta(2\alpha(y-\sigma)+(1-\gamma))}{\gamma\alpha+(1-\gamma)\theta}$, and the freelancer's quality level is $q^* = \frac{(1-\gamma)\theta(2\alpha(y-\sigma)+(1-\gamma))}{2\alpha(\gamma\alpha+(1-\gamma)\theta)}$. In this case,*

will choose the option that does not lead to a dispute. For example, if $h^*(q) = 1$, the client will accept the freelancer's work instead of rejecting the work if the freelancer will subsequently initiate the dispute and win. Correspondingly, the minimum $q$ that satisfies $h^*(q) = 1$ (see Lemma 1.1) defines the threshold for the client to accept the freelancer's work. Such a threshold equilibrium structure is preserved if the model explicitly captures a hassle cost of dispute, in which case the threshold will correspond to a quality level that makes $h^*(q) < 1$ and our insights remain unaffected.

*the client rejects the freelancer's work and the freelancer initiates a dispute. Moreover, the platform's equilibrium utility is* $\Pi^* = h^*(q^*)\gamma p^* + f^* - \frac{\gamma^2(p^*)^2}{16\theta\sigma^2}$.

Proposition 1.1(i) shows that the equilibrium can fall into three regimes depending on the skill level of the freelancer. First, if the freelancer's skill level is high (i.e., $\alpha \leq \underline{\alpha}_c$), contracting occurs without dispute. Second, if the freelancer's skill level is medium (i.e., $\underline{\alpha}_c < \alpha \leq \bar{\alpha}_c$), contracting occurs with dispute. Third, if the freelancer's skill level is low (i.e., $\alpha > \bar{\alpha}_c$), contracting does not occur. For the first two regimes where contracting occurs, Proposition 1.1(ii-iii) characterizes the equilibrium decisions of all decision-makers, including the platform, the client, and the freelancer.

If the freelancer's skill level is sufficiently high (i.e., $\alpha \leq \underline{\alpha}_c$), he is able to choose a quality level that is sufficiently high to guarantee winning the dispute. This indicates that the client does not have any incentive to reject the freelancer's work and run into a dispute. As a result, the client will accept the freelancer's work and dispute does not occur in equilibrium. In this case, the freelancer does not pay any dispute fee in equilibrium. However, the dispute fee influences the equilibrium contract price. In order to incentivize the freelancer to participate, the client's contract price needs to cover both the commission fee and the dispute fee (i.e., $(1-\gamma)p \geq f$). The freelancer will not participate if the client's contract price net of commission is less than the dispute fee, because if the client deviates from the equilibrium by rejecting to pay, the freelancer will not be able to afford the dispute. Thus, the client's equilibrium contract price satisfies $p^* = \frac{f^*}{1-\gamma}$, which indicates that the platform can use the dispute fee to nudge the client to offer a higher price to the freelancer. In this case, the platform's equilibrium utility comprises solely the commission revenue.

If the freelancer's skill level is medium (i.e., $\underline{\alpha}_c < \alpha \leq \bar{\alpha}_c$), while contracting still occurs, it will lead to a dispute in equilibrium. Dispute occurs in this case because it is too costly for a freelancer with an insufficient skill level to choose a sufficiently high quality level to guarantee winning the dispute. Anticipating this, the client will reject the freelancer's work so that she will not have to pay if the freelancer ends up losing the dispute. Correspondingly, the freelancer will respond by initiating the dispute, because he can only earn the contract price by winning the dispute. In this case, the platform's utility comprises both the commission fee and the dispute fee, as well as the disutility due to its deviation from the industry norm in dispute resolution. Moreover, it is increasingly costly for a lower-skilled freelancer to participate due to the higher quality cost and lower probability of winning the dispute. Therefore, if the freelancer's skill level is too low (i.e., $\alpha > \bar{\alpha}_c$), he is not able to participate.

## 1.5 Decentralized Dispute System

In this section, we study the decentralized dispute system, where disputes are resolved by a tribunal comprising a separate group of platform users. Each member of the tribunal votes between the freelancer and the client, and the decision of the tribunal is based on the majority rule. In Section 1.5.1, we first introduce the model of the voting game. Then in Section 1.5.2, we derive the equilibrium of the voting game. Finally, building on the tribunal's voting equilibrium, we proceed to analyze the overall game between the client, the freelancer, and the platform in Section 1.5.3.

### 1.5.1 Tribunal's Voting Game

We first consider the subgame of the tribunal's dispute resolution given that a dispute has been initiated. Recall that an important feature introduced by the emerging platforms is a self-funded mechanism where the voters who vote for the winning side will share the total deposit from all voters. This can create an incentive for voters to prioritize earning more monetary reward in their decisions, rather than voting solely based on the evaluation of the freelancer's work quality. Furthermore, in order to earn the monetary reward, a voter must ensure that he votes for the winning side, which means that his vote coincides with the majority of votes. Thus, the voters' decisions become strategic complements of each other (i.e., a voter's relative gain from voting for a particular side over the other side increases when the proportion of voters voting for that side increases), leading to a *coordination game*. Such coordination would require a voter to strategically anticipate the decisions of other voters when making his own decision, without knowing who the other voters are.

To model the strategic interaction among the voters in the tribunal, we adopt the *global games* framework commonly used for studying coordination games (e.g., Morris and Shin 1998, Edmond 2013, Rundlett and Svolik 2016). This framework assumes that players receive private but correlated signals of an underlying fundamental, and their payoffs are jointly determined by the decisions of all players. Consistent with the global games framework, we model the voters in the tribunal as a continuum with total mass normalized to one, to approximate a large but finite number of voters. In our setting, the signal that voter $i$ privately receives is his own evaluation of the freelancer's work quality, which is modeled as $x_i = q + \sigma\epsilon_i$, where $q$ is the true quality unobservable to the voters, $\epsilon_i$ is a random variable uniformly distributed over $[-1, 1]$, and $\sigma$ is the scaling factor that measures the degree of subjectivity in the voters' evaluations. We assume that the degree of subjectivity is the same for any external evaluator, including the platform's dispute team members and the voters in a tribunal, as it is a characteristic of the general population (Rowe and Wright 2001). In Section 1.9.5, we explore a model extension where the degree of subjectivity can be different under the two systems.

Different from the platform's dispute decision, a voter's decision needs to factor in his inferences about other voters' decisions, which hinges on his belief about the true quality of the freelancer's work. Following the global games framework, we assume that the voters initially have a uniform prior on the true quality of work and after observing their own evaluated quality, the voters update their belief about the true quality of work and draw inferences about the decisions of other voters. As a result, if a voter receives a high signal, he is likely to believe that the other voters receive high signals as well. It is worth mentioning that the global games framework requires that the voters cannot communicate with each other so that they cannot collude in their voting decisions. The emerging platforms have adopted several measures to prevent communication among the voters: 1) the voters are randomly assigned to dispute cases, so they do not know apriori which case they will be assigned to, 2) the platform does not establish any communication channels for the voters to communicate with each other, and 3) the time window for the voters to submit their votes is typically limited to 24 hours, which further reduces the chance of finding and communicating with other voters in the same tribunal. These measures lead to an opacity in the composition of the tribunal, which helps to prevent collusion among the voters and also makes the global games framework applicable.

To gain the right to vote in the tribunal, each voter must pay a participation fee of $t$. The total participation fees are pooled together to form the reward pool for the dispute case. Voters who are part of the majority votes will win an even share of the total reward. Consistent with the platform's decision under the centralized dispute system, voter $i$ chooses a quality threshold $k_i$ such that he votes for the freelancer if $x_i \geq k_i$ and votes for the client if $x_i < k_i$. Given that $l$ proportion of voters vote for the freelancer, the utility of voter $i$, $u_i(x_i, k_i, l)$, is as follows:

$$u_i(x_i, k_i, l) = \left[\mathbf{1}_{l \geq 0.5}\left(\frac{t}{l}\mathbf{1}_{x_i \geq k_i} - t\right) + \mathbf{1}_{l < 0.5}\left(\frac{t}{1-l}\mathbf{1}_{x_i < k_i} - t\right)\right] - \xi(k_i - y)^2. \tag{1.5}$$

To determine his threshold strategy $k_i$, voter $i$ needs to consider all possible values of $x_i$ and his voting decision given each $x_i$ should maximize his expected utility by taking expectation of Equation (1.5) based on his belief about $l$.

As Equation (1.5) shows, similar to the platform's utility, a voter's utility comprises two components. The first component is the voter's monetary payoff if voting for the winning side, which is the difference between the share of the total reward and the participation fee. For example, when the majority of the voters vote for the freelancer (i.e., $l \geq 0.5$), a voter will receive a reward of $\frac{t}{l}$ if he also votes for the freelancer (i.e., if $x_i \geq k_i$), and zero if he votes for the client (i.e., if $x_i < k_i$). The second component corresponds to a disutility of "guilt" which may weigh on the voter's conscience if he does not let a worthy freelancer win and is weighted by a factor of $\xi > 0$. This disutility term mirrors the platform's disutility of deviating from the industry norm and is modeled consistently as a quadratic function of the distance between voter $i$'s threshold $k_i$ and the industry standard $y$. The inclusion of such a non-monetary component in a voter's utility follows the convention of voting game models, where the voters receive a disutility for convicting an innocent party or acquitting a guilty party (e.g., Feddersen and Pesendorfer 1998, Kojima and Takagi 2010). Moreover, a utility model with both monetary and non-monetary components is commonly used in behavioral modeling (e.g., Falk and Fischbacher 2006, Battigalli and Dufwenberg 2007, Battigalli and Dufwenberg 2009).

### 1.5.2 When Can Tribunal Voting Achieve Justice?

Given the voting game described in Section 1.5.1, we now analyze the equilibrium voting strategy of tribunal members and examine under what conditions the tribunal voting mechanism can achieve justice of dispute resolution. As we have seen, the self-funded mechanism creates an incentive for the voters to coordinate their votes, as a voter only receives a monetary reward by being part of the majority. However, it remains unclear if such coordination can be achieved in equilibrium and all voters can reach agreement on the same quality threshold to follow in their voting decisions. If there exist multiple equilibria corresponding to different thresholds, the voting game may result in a *coordination failure* (Van Huyck et al. 2002). Moreover, even if the voters can coordinate their decisions by agreeing on the same threshold to follow, it is still unclear if the outcome of their coordination can be a *fair equilibrium* where all voters follow the industry standard (i.e., $k_i = y$).

To ensure that the decentralized dispute system achieves justice, two conditions must be satisfied. First, a fair equilibrium must exist and arise as an equilibrium of the voting game. Second, it must be the unique equilibrium of the voting game. These conditions together guarantee that the tribunal voting will follow the industry standard and achieve a fair resolution of disputes. Therefore, we derive conditions for the existence and uniqueness of the fair equilibrium. Lemma 1.2 first shows the existence of the fair equilibrium and derives the resulting winning probability of the freelancer under this equilibrium.

**Lemma 1.2** *(i) Under the decentralized dispute system, voter i choosing $k_i^+ = y$ as the quality threshold is always an equilibrium of the tribunal's voting game.*

*(ii) Under this equilibrium, the probability of the freelancer winning the dispute is*

$$h^+(q) = \begin{cases} 0 & \text{if } q \leq y - \sigma, \\ \frac{q-y+\sigma}{2\sigma} & \text{if } y - \sigma < q < y + \sigma, \\ 1 & \text{if } q \geq y + \sigma, \end{cases}$$

*which is increasing in q and decreasing in y.*

Lemma 1.2 shows that the fair equilibrium always exists in the tribunal's voting game. In this case, each voter will vote for the freelancer if the evaluated quality is higher than $y$, and will vote for the client otherwise. Collectively, the voters' voting strategies form a probability distribution, such that as the freelancer's quality $q$ increases, his winning probably $h^+(q)$ also increases.[2] Moreover, by comparing $h^+(q)$ to the freelancer's winning probability $h^*(q)$ under the centralized dispute system (Lemma 1.1), we observe that given the same quality level, the freelancer has a lower chance of winning the dispute under the

[2]Consistent with voting game models with a continuum of voters (e.g., Baron 1994, Bidwell et al. 2020), we approximate the freelancer's winning probability using the proportion of voters who vote for the freelancer. This makes the winning probability continuously increasing in the work quality and behave more consistently with that under a model with a finite number of voters, whereas without the approximation, the winning probability would be a 0-1 discontinuous function due to the voters being a continuum. Previous research has shown that this approach does not alter the economic insights for voting games (e.g., Grossman and Helpman 1996).

decentralized dispute system. The decentralized dispute system removes the platform's bias of ruling in favor of the freelancer in order to earn more commissions, and the industry norm serves as a focal point for the tribunal's voting. This results in a higher quality standard that is expected of a freelancer under the decentralized dispute system, and the freelancer has to offer a higher quality level in order to achieve the same winning probability.

While the voters' strategic decision-making to earn more monetary rewards does not necessarily prevent the fair equilibrium from being an equilibrium of the voting game, its mere existence is not sufficient to guarantee a just dispute resolution outcome by the tribunal. If an unfair equilibrium, corresponding to a different threshold than the industry standard, exists simultaneously, a coordination failure may occur, making it impossible to ensure the tribunal selects the fair equilibrium. Therefore, we next establish a condition for the fair equilibrium identified in Lemma 1.2 to become the unique equilibrium of the tribunal's voting game, which is given by Proposition 1.2 below.

**Proposition 1.2** *If* $\sigma > \sqrt{\frac{t(\frac{1}{2}+\ln(2))}{\xi}}$, *the equilibrium in Lemma 1.2 is the unique equilibrium of the tribunal's voting game.*

The condition established in Proposition 1.2 requires a sufficiently high degree of subjectivity in the voters' evaluations, as indicated by the requirement for a sufficiently large $\sigma$. To prevent any unfair equilibrium, the voters must have an incentive to deviate to a fairer equilibrium by moving their quality threshold closer to the industry standard, thereby reducing the disutility of guilt they incur. However, changing the threshold from that of the majority of voters also reduces their probability of being on the winning side, which in turn decreases their monetary payoff. Whether the voters have an incentive to deviate to a fairer equilibrium is determined by the trade-off between the incentive to reduce guilt (i.e., the gain of being fair) and the incentive to lose less monetary reward (i.e., the cost of being fair).

If the degree of subjectivity is high, voters tend to have more diverse judgments for a given dispute case. If a voter changes his threshold, the probability of flipping from the winning to the losing side is small because the majority of voters are unlikely to fall between the old and new thresholds of that voter. Consequently, a voter's loss in monetary reward is relatively insensitive to the quality threshold he chooses, and he is less concerned about not aligning his threshold with that of other voters when other voters are being unfair. Therefore, a higher degree of subjectivity reduces the cost of being fair. When the degree of subjectivity is sufficiently high, the incentive to deviate towards the industry standard is guaranteed to exist for any threshold unequal to the industry standard, making it the only threshold that can sustain as an equilibrium in the voting game.

However, if the degree of subjectivity is low, voters are likely to have similar evaluations for a given dispute case, making their winning probability sensitive to deviations from the threshold chosen by the majority of voters. If the majority of voters have coordinated on a threshold that is not too different from the industry standard, the remaining voters will agree to follow the same threshold and compromise on fairness, since it is too costly to deviate towards the industry standard. This creates a greater incentive to conform to other voters' decisions, making a threshold unequal to the industry standard a possible equilibrium. Additionally, a lower degree of subjectivity enlarges the range of thresholds that the voters can agree on, leading to multiple equilibria and a coordination failure in the voting game. Therefore, a lower degree of subjectivity increases the cost of being fair and reduces the tribunal's ability to achieve a just dispute resolution outcome.

The condition in Proposition 1.2 has important implications for how the platform can ensure that the fair equilibrium is the unique equilibrium of the voting game. When adopting the decentralized dispute system, the platform should be cautious about any policy that may reduce the degree of subjectivity in the voters' judgments, and the value of the decentralized dispute system lies critically in its ability to elicit diverse opinions from the tribunal members. Dispute evaluation guidelines provided by the platform should not aim to homogenize the voters' evaluations, as a more homogenized voter judgment may incentivize voters to prioritize conforming to each other and forgo their objective to achieve justice.

Moreover, since the degree of subjectivity can be influenced by the nature of the task being evaluated, the condition in Proposition 1.2 also implies that the tribunal voting mechanism may not work equally well for all types of tasks. For tasks such as home cleaning and programming, objective evaluation criteria are easily defined and the evaluators' judgments tend to be less subjective. Platforms should exercise caution when decentralizing dispute resolution in this case, as a lower degree of subjectivity limits the ability of the decentralized disputes system to elicit diverse opinions from the voters. However, for tasks such as design works, objective evaluation criteria are difficult to define and the evaluators' judgments rely heavily on their personal preferences, leading to a higher degree of subjectivity. In this case, the decentralized dispute system can maximize its potential to elicit diverse opinions from the voters and ensure a just dispute resolution outcome.

In addition, the condition in Proposition 1.2 also depends on two other parameters: $t$, the voters' participation fee, and $\xi$, the weight that voters place on fairness consideration. Holding the tribunal's degree of subjectivity constant, the fair equilibrium is guaranteed to be the unique equilibrium if the voters' participation fee is sufficiently small, or if their weight on fairness consideration is sufficiently high. A lower participation fee reduces the reward pool and the voters' incentive to conform to each other, while a higher weight on fairness consideration strengthens their incentive to deviate towards the industry standard from any threshold unequal to the industry standard. Both changes increase the likelihood of achieving a just dispute resolution outcome. Therefore, the platform should avoid setting a participation fee that is too high and consider educating the voters to prevent them from gaming the system.

Having obtained the measures that the platform can take to induce the fair equilibrium as the unique equilibrium of the tribunal's voting game, we proceed to analyze the overall game between the client, the freelancer, and the platform, with the fair equilibrium in Lemma 1.2 as the dispute resolution outcome.

### 1.5.3 Contracting Equilibrium Under Decentralized Dispute System

Given the equilibrium of the tribunal voting subgame obtained from Section 1.5.2, we continue the backward induction process of the overall game to solve for the contracting equilibrium under the decentralized dispute system. If both the client and the freelancer participate, their utilities are similar to Equations

(1.2) and (1.3) respectively with $h^*(q)$ replaced by $h^+(q)$ (i.e., the freelancer's probability of winning the dispute under the decentralized dispute system). The platform's utility is given by

$$\Pi(f) = \begin{cases} h^+(q)(\gamma p + f) + (1 - h^+(q))f & \text{if client rejects and freelancer disputes,} \\ 0 & \text{if client rejects and freelancer does not dispute,} \\ \gamma p & \text{if client accepts.} \end{cases} \tag{1.6}$$

Notice that if dispute occurs, the platform does not incur any disutility from the outcome of dispute resolution when the tribunal's quality threshold resulting from the voting game is equal to the industry standard (Lemma 1.2). Proposition 1.3 characterizes the equilibrium under the decentralized dispute system.

**Proposition 1.3** *(i) Under the decentralized dispute system, there exist two thresholds, $\bar{\alpha}_d$ and $\underline{\alpha}_d$ (where $\bar{\alpha}_d \geq \underline{\alpha}_d$), such that contracting occurs if and only if $\alpha \leq \bar{\alpha}_d$, and given that contracting occurs, dispute occurs if $\underline{\alpha}_d < \alpha \leq \bar{\alpha}_d$ and does not occur if $\alpha \leq \underline{\alpha}_d$.*

*(ii) If $\alpha \leq \underline{\alpha}_d$, the platform's dispute fee is $f^+ = (1 - \gamma)(y + \sigma)$, the client's contract price is $p^+ = y + \sigma$, and the freelancer's quality level is $q^+ = y + \sigma$. In this case, the client accepts the freelancer's work. Moreover, the platform's equilibrium utility is $\Pi^+ = \gamma p^+$.*

*(iii) If $\underline{\alpha}_d < \alpha \leq \bar{\alpha}_d$, the platform's dispute fee is $f^+ = \frac{(2\alpha(y-\sigma)+(1-\gamma))(-2\alpha(y-\sigma)+(1-\gamma))}{4\alpha}$, the client's contract price is $p^+ = \frac{2\sigma(2\alpha(y-\sigma)+(1-\gamma))}{1-\gamma}$, and the freelancer's quality level is $q^+ = \frac{1-\gamma}{2\alpha} + y - \sigma$. In this case, the client rejects the freelancer's work and the freelancer initiates a dispute. Moreover, the platform's equilibrium utility is $\Pi^+ = h^+(q^+)\gamma p^+ + f^+$.*

Proposition 1.3 shows that the equilibrium under the decentralized dispute system can fall into three regimes depending on the skill level of the freelancer, similar to the centralized dispute system: contracting occurs without dispute if $\alpha \leq \underline{\alpha}_d$, contracting occurs with dispute if $\underline{\alpha}_d < \alpha \leq \bar{\alpha}_d$, and contracting does not occur if $\alpha > \bar{\alpha}_d$. However, there are notable differences. Most importantly, as we have seen from Section 1.5.2, the tribunal's dispute decision eliminates the platform's decision-making bias that arises under centralized decision-making. The resulting differences in the equilibrium can be clearly seen by comparing Proposition 2(iii) to Proposition 1(iii). For example, the platform no longer incurs the disutility, $\frac{\gamma^2(p^*)^2}{16\theta\sigma^2}$, due to the deviation from the industry norm.

Under the centralized dispute system, the platform's bias in favor of the freelancer can cause the client to have reservations in offering a higher contract price to the freelancer. This is because an increased contract price can further amplify the platform's bias, which in turn creates a counter force in incentivizing the freelancer to choose a higher quality level. In contrast, the decentralized dispute system eliminates the platform's bias and raises the quality threshold required for the freelancer to win the dispute. This can make the client more willing to offer a higher contract price. As a result, the incentives of the client and the freelancer are more aligned under the decentralized dispute system.

## 1.6 Value of Decentralization

In this section, we compare the centralized and decentralized dispute systems and derive insights regarding the type of markets they each cater to as well as the value of decentralizing dispute resolution. In Section 1.6.1, we first compare the equilibrium decisions of the client, the freelancer, and the platform. In Section 1.6.2, we examine when the platform should adopt the decentralized dispute system. In Section 1.6.3, we examine when the decentralized dispute system can improve social welfare.

### 1.6.1 Equilibrium Comparison

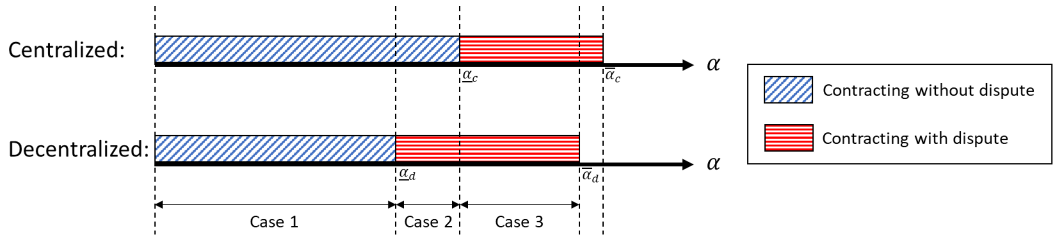
As seen in Sections 1.4 and 1.5, under both systems, the equilibrium is characterized by three regimes depending on the skill level of the freelancer. We start by comparing the thresholds on the freelancer's skill level that define the three equilibrium regimes, to gain a first understanding of how the decentralized dispute system can change the equilibrium structure.

**Theorem 1.1** *(i) Contracting occurs in fewer cases under the decentralized dispute system (i.e., $\bar{\alpha}_d \leq \bar{\alpha}_c$).*

*(ii) Dispute is prevented in fewer cases under the decentralized dispute system (i.e., $\underline{\alpha}_d \leq \underline{\alpha}_c$).*

Theorem 1.1 shows that the decentralized dispute system reduces the range of the freelancer's skill level $\alpha$ for contracting to occur, and also reduces the range where dispute can be prevented. Recall from Section 1.4 that the centralized dispute system leads to a decision-making bias of the platform to let the freelancer win the dispute with a higher probability because of its interest to earn the commission. Thus, a lower quality is expected of the freelancer and it is less costly for the lower-skilled freelancers to participate under the centralized dispute system (i.e., $\bar{\alpha}_d \leq \bar{\alpha}_c$). Moreover, the platform's bias in favor of the freelancer also causes the client to be more willing to compromise on quality. This pushes the client to accept the freelancer's work and prevents dispute in more cases (i.e., $\underline{\alpha}_d \leq \underline{\alpha}_c$).

Figure 1.2: The $\alpha$ thresholds under both centralized and decentralized dispute systems.




The comparisons of the $\alpha$ thresholds are illustrated in Figure 1.2. To ease our subsequent analyses, we define Case 1 as the "high-skill" case where dispute does not occur under either system (i.e., $\alpha \leq \underline{\alpha}_d$), Case 2 as the "medium-skill" case where dispute occurs under the decentralized dispute system but not under the centralized dispute system (i.e., $\underline{\alpha}_d < \alpha \leq \underline{\alpha}_c$), and Case 3 as the "low-skill" case where dispute occurs under both systems (i.e., $\underline{\alpha}_c < \alpha \leq \bar{\alpha}_d$).[3] We focus on these three cases where contracting occurs under both systems (i.e., $\alpha \leq \bar{\alpha}_d$) in our subsequent analyses and make references to them in our discussions. Theorem 1.2 summarizes the comparison of the equilibrium decisions of the freelancer, the client, and the platform between the two systems.

**Theorem 1.2** *(i) There exists a threshold $\alpha_q$ (where $\underline{\alpha}_d < \alpha_q \leq \underline{\alpha}_c$) such that the equilibrium quality level is higher under the decentralized dispute system (i.e., $q^+ \geq q^*$) if $\alpha \leq \alpha_q$ or $\alpha > \underline{\alpha}_c$, and is lower under the decentralized dispute system (i.e., $q^+ < q^*$) if $\alpha_q < \alpha \leq \underline{\alpha}_c$.*

*(ii) There exists a threshold $\alpha_p$ (where $\underline{\alpha}_d < \alpha_p \leq \underline{\alpha}_c$) such that the equilibrium contract price is higher under the decentralized dispute system (i.e., $p^+ \geq p^*$) if $\alpha \leq \alpha_p$ or $\alpha > \underline{\alpha}_c$, and is lower under the decentralized dispute system (i.e., $p^+ < p^*$) if $\alpha_p <$*

[3] We note that $\underline{\alpha}_c < \bar{\alpha}_d$ (hence Case 3 exists) if and only if $\sigma > \bar{\sigma}$, where $\bar{\sigma} = \frac{\sqrt{(\gamma+2\theta y)^2+16\gamma\theta y}-\gamma+2\theta y}{12\theta}$; otherwise, Case 3 degenerates.

$\alpha \leq \underline{\alpha}_c$.

*(iii) When dispute occurs under both systems (i.e., $\underline{\alpha}_c < \alpha \leq \bar{\alpha}_d$), there exists a threshold $\alpha_f$ (where $\underline{\alpha}_c < \alpha_f \leq \bar{\alpha}_d$) such that the equilibrium dispute fee is higher under the decentralized dispute system (i.e., $f^+ \geq f^*$) if $\alpha \leq \alpha_f$, and is lower under the decentralized dispute system (i.e., $f^+ < f^*$) if $\alpha > \alpha_f$.*

Theorem 1.2(i-ii) shows that under the same equilibrium regime, such that either dispute occurs under both systems (i.e., Case 3) or dispute does not occur under either system (i.e., Case 1), the decentralized dispute system induces a higher quality level and contract price compared to the centralized dispute system. As we have seen, the decentralized dispute system eliminates the platform's bias of ruling in favor of the freelancer and raises the quality threshold for the freelancer to win the dispute. The freelancer needs to factor in how stringent the quality standard is in order to win the dispute (i.e., Case 3) or prevent the dispute (i.e., Case 1). In both cases, the higher standard of dispute resolution increases the freelancer's incentive to improve quality under the decentralized dispute system, and hence the client is willing to offer a higher contract price. However, it is possible for the decentralized dispute system to induce a lower quality level and contract price when the equilibrium regimes are different under the two systems. In Case 2, dispute only occurs under the decentralized dispute system but not under the centralized dispute system. This means that the freelancer has to pay the dispute fee under the decentralized dispute system, which would constrain how much effort he can expend to improve quality. We further find that when the freelancer's skill level is relatively low within Case 2 (i.e., $\alpha_q < \alpha < \underline{\alpha}_c$), this constraint will outweigh the quality-improving incentive due to the elimination of the platform's bias, leading to a lower equilibrium quality level under the decentralized dispute system. Correspondingly, the client would offer a lower contract price.

We next turn to the platform's dispute fee. Theorem 1.2(iii) shows that when dispute occurs under both systems (i.e., Case 3), the equilibrium dispute fee is higher under the decentralized dispute system if the freelancer's skill level is relatively high (i.e., $\alpha \leq \alpha_f$), and is lower if the freelancer's skill level is relatively low (i.e., $\alpha > \alpha_f$). As the freelancer's skill level decreases (i.e., $\alpha$ increases), his equilibrium quality level decreases and it is increasingly difficult for the him to win the dispute. Nevertheless, the platform can reduce its quality threshold under the centralized dispute system, while it does not decide how the tribunal would judge the freelancer's work under the decentralized dispute system. Thus, as the freelancer's skill level decreases, his equilibrium probability of winning the dispute would decrease at a slower rate under the centralized dispute system. This indicates that a lower-skilled freelancer will receive a greater advantage under the centralized dispute system and is hence willing to pay a higher dispute fee relative to the decentralized dispute system. Thus, when the freelancer's skill level decreases below a certain threshold (i.e., $\alpha_f$), the platform would be able to charge a higher dispute fee under the centralized dispute system.

### 1.6.2 When is Decentralized Dispute System More Profitable?

To gain an insight into how the decentralized dispute system performs with respect to the centralized dispute system, we next compare the platforms' equilibrium utilities under the two dispute systems to uncover which system the platform should choose.

**Theorem 1.3** *Suppose $\gamma \leq \frac{1}{3}$ and $\sigma \leq y$. There exists a threshold $\bar{\alpha}$ (where $\underline{\alpha}_d \leq \bar{\alpha} \leq \bar{\alpha}_d$) such that the platform's equilibrium utility is higher under the decentralized dispute system (i.e., $\Pi^+ \geq \Pi^*$) if $\alpha \leq \bar{\alpha}$, and is lower under the decentralized dispute system (i.e., $\Pi^+ < \Pi^*$) if $\alpha > \bar{\alpha}$.*

Theorem 1.3 characterizes, under the conditions of $\gamma \leq \frac{1}{3}$ and $\sigma \leq y$, that the platform can achieve a higher utility under the decentralized dispute system only when the freelancer's skill level is sufficiently high (i.e., $\alpha \leq \bar{\alpha}$). We first note that the conditions in Theorem 1.3 are unlikely to eliminate scenarios that are practically relevant. First, a commission rate higher than $\frac{1}{3}$ is uncommon for online labor platforms. Second, given that the evaluated quality (by both the platform and the voters) follows a uniform distribution over $[q - \sigma, q + \sigma]$, $\sigma \leq y$ ensures that if the freelancer's quality level is equal to the industry standard $y$, the evaluated quality is non-negative. In addition, in Appendix A.5, we show numerically that Theorem 1.3 still holds even when these conditions are not imposed. Moreover, if $\bar{\alpha}_d < \alpha \leq \bar{\alpha}_c$ (i.e., the region beyond Case 3), contracting only occurs under the centralized dispute system, hence the centralized dispute system dominates the decentralized dispute system. Thus, the result in Theorem 1.3 extends to the region beyond the three cases of interest (i.e., $\alpha \leq \bar{\alpha}_d$).

Since $\underline{\alpha}_d \leq \bar{\alpha} \leq \bar{\alpha}_d$, the threshold $\bar{\alpha}$ can be achieved in Case 2 or Case 3, but not in Case 1. This immediately indicates that when dispute does not occur under either system (i.e., Case 1), the platform is better off with the decentralized dispute system. If the freelancer's skill level is sufficiently high, dispute does not occur and the platform only earns the commission fee. As discussed previously in Theorem 1.2, the elimination of the platform's bias under the decentralized dispute system induces the freelancer to provide a higher quality level and the client to offer a higher contract price. Thus, the platform can extract more commission under the decentralized dispute system.

If the freelancer's skill level is not sufficiently high, dispute can occur (i.e., Cases 2 and 3). When dispute occurs, the platform's revenue structure changes to one that depends on both the dispute fee and the commission fee. The platform is guaranteed to earn the dispute fee as long as dispute occurs, but only earns the commission fee if the freelancer wins the dispute. Depending on the skill level of the freelancer, the platform can extract more surplus from the participants through different means. When the freelancer's skill level is relatively high, he would be able to win the dispute with a high probability. This indicates that the platform will earn the commission fee with a high probability, hence its revenue is more dependent on the commission fee. Because the decentralized dispute system can induce the client to offer a higher contract price, the platform can earn a higher commission under the decentralized dispute system, and hence the decentralized dispute system would make the platform better off. In contrast, when the freelancer's skill level is relatively low, he can only win the dispute with a low probability. This indicates that the platform has to rely more on the dispute fee. As we have seen in Theorem 1.2, the platform's bias creates a greater advantage for lower-skilled freelancers, which enables the platform to charge a higher dispute fee under the centralized dispute system. Thus, the centralized dispute system would make the platform better off in this case.

Therefore, the decentralized dispute system can only benefit the platform when the freelancers' skill levels are sufficiently high. With higher-skilled freelancers, the platform would be able to utilize the tribunal to improve the incentive structure of participants and extract more commissions. However, with lower-skilled freelancers, the platform would benefit from retaining the decision-making power to arbitrate disputes to itself. By doing so, the platform can set a lower quality standard for lower-skilled freelancers and extract more dispute fees from them; whereas under the decentralized dispute system, the more stringent quality standard set by the tribunal would make it disproportionately more costly for the lower-skilled freelancers to participate and more of them can be weeded out.

Our results suggest that different types of dispute resolution systems can cater to different market segments. The decentralized dispute system is more suitable when the freelancer pool is higher-skilled, while the centralized dispute system is more suitable when the freelancer pool is lower-skilled. Therefore, for the emerging platforms to succeed with the decentralized dispute system, it is important to ensure the skill level of their freelancer pool. This can be achieved by providing better training to the freelancers, such as by partnering with online learning platforms (e.g., Coursera or Udemy), or adopting a stricter screening and certification process. For example, Upwork encourages its freelancers to obtain verifiable certifications such as Adobe or Oracle, and Freelancer.com has internal programming and language tests for the freelancers to take.

Moreover, the freelancers' skill levels may improve over time for the traditional platforms. The majority of the tasks in companies have been shifting to a project-based structure, under which companies can utilize external workforce who are able to work remotely (Claussen et al. 2018). Thus, the freelancer market is expected to grow and more professional employees will utilize the online labor platforms (Katz and Krueger 2019). Such an influx of professional employees may increase the overall skill level of the freelancer pool. As a result, it may become optimal for these platforms to switch to the decentralized dispute system in order to reap greater benefits.

### 1.6.3 Social Impact of Decentralized Dispute System

Lastly, we investigate the impact of the decentralized dispute system on the social welfare. We have previously seen from Section 1.5 that the decentralized dispute system can be designed to deliver its promise of attaining a fairer dispute resolution than the centralized dispute system. As a result of having a fairer dispute resolution, the decentralized dispute system is able to induce a higher quality level in most cases (Theorem 1.2). However, a higher quality level does not always improve the social welfare. If the quality level already exceeds the socially optimal level, an even higher quality standard would cause the quality improvement incentive to deviate from that of a social planner and reduce the social welfare.

The social welfare in our model is $q - \alpha q^2$, and the socially optimal quality level is $\frac{1}{2\alpha}$. We are particularly interested in whether a higher quality level automatically translates into a more socially optimal outcome. To this end, Theorem 1.4 characterizes a condition such that the decentralized dispute system is able to attain a higher social welfare, given that it induces a higher equilibrium quality level than the centralized dispute system.

**Theorem 1.4** *When the equilibrium quality level is higher under the decentralized dispute system (i.e., $q^+ \geq q^*$), there exists a threshold $\bar{y}(\alpha)$ for every $\alpha$ such that the equilib-*

*rium quality level under the decentralized dispute system is closer to the socially optimal quality level* $\frac{1}{2\alpha}$ *if and only if* $y \leq \bar{y}(\alpha)$. *Furthermore, under the same equilibrium regime (as defined in Figure 1.2),* $\bar{y}(\alpha)$ *is decreasing in* $\alpha$.

As shown in Theorem 1.4, if the public is overly demanding on quality (i.e., $y > \bar{y}(\alpha)$), the freelancer's effort may be overly exerted and the decentralized dispute system will result in a quality level that deviates further away from the socially optimal level than that under the centralized dispute system (i.e., $|q^+ - \frac{1}{2\alpha}| > |q^* - \frac{1}{2\alpha}|$). Thus, the industry standard $y$ cannot be too high for the equilibrium outcome to be more socially optimal under the decentralized dispute system. Moreover, the threshold of how stringent the industry standard needs to be, $\bar{y}(\alpha)$, is dependent on the freelancer's skill level, $\alpha$. Theorem 1.4 further shows that under the same equilibrium regime, a lower-skilled freelancer would need a less stringent industry standard in order for the decentralized dispute system to result in a more socially optimal outcome. Therefore, to make sure that gig platforms' adoption of the decentralized dispute system does not hurt the social welfare, a social planner should be mindful of the industry norm and take necessary measures to prevent the public from forming a standard that is overly stringent.

In addition, other studies have shown that most people tend to lose empathy and deviate from the norm as their influence and authority grow (Schaarschmidt 2017). Thus, it is important to manage the norm of the people with authority to ensure that the standard does not go exceedingly stringent over time. Such management of the norm is especially crucial under the decentralized dispute system, as the authority of the dispute decision has been surrendered by the platform to the voters. This may result in the standard becoming overly stringent if the voters' authority goes unchecked. Thus, a totally hands-off approach towards the decentralized dispute system may not be advisable. One possible solution is for the platform to set guidelines or principles for the voters to follow when they are evaluating the dispute case. Such recommended guidelines can serve as a focal point for the voters to form their decisions, so that the voting mechanism of the tribunal can induce a more socially optimal quality level. This helps to ensure that the decentralized dispute system not only can be more profitable for the platform, but also can improve the social welfare at the same time.

## 1.7 Extensions

In addition to the main model presented in previous sections, we also generalize the model in several directions to test the robustness of our main insights regarding when the decentralized dispute system should be preferred by the platform, and obtain additional insights regarding how the platform's preference can be affected by other factors. In this section, we present a summary of seven model extensions we analyze. The detailed model formulation and results are provided in Section 1.9.1 to 1.9.7, and the proofs of results for the model extensions are presented in Appendix A.6 to A.11.

### 1.7.1 Third-Party Arbitration

In Section 1.9.1, we extend the model of the centralized dispute system to allow the freelancer and the client to appeal the platform's decision, in which case a third-party arbitrator will be involved to re-evaluate the dispute case and make a binding decision. This adds two more decision-making stages to the sequence of events, namely an "appealing" stage and a "third-party arbitration" stage. The third-party arbitrator chooses its own threshold to evaluate the freelancer's work, taking into consideration both the industry standard and the decision of the platform. We find that regardless of the involvement of a third-party arbitrator, the decentralized dispute system dominates the centralized dispute system when the freelancer's skill level is sufficiently high. Moreover, a third-party arbitrator whose incentive is more aligned with the platform can hurt the platform under the centralized dispute system and make the decentralized dispute system the preferred system in more cases. Thus, if the platform cannot convince its users that the third-party arbitrator is impartial, fully decentralizing dispute resolution to individual platform users can remove the need for the platform to commit to a fairer dispute resolution, since the decision-making process is entirely entrusted to independent parties with no conflicts of interest.

### 1.7.2 Price-Dependent Industry Standard

In Section 1.9.2, we allow the industry standard to be contingent on the contracting terms, hence the contracting parties are able to influence the industry standard. Specifically, we assume that the industry standard is a linear increasing function of the contract price. We find that the decentralized dispute system dominates the centralized dispute system when the industry standard is less sensitive to the contract price. Moreover, we confirm that our main insight about the value of decentralizing dispute system is not driven by the platform users' lack of power in influencing the industry standard, as our previous finding that the decentralized dispute system performs better with higher-skilled freelancers continues to hold.

### 1.7.3 Double-Sided Dispute Fees

In Section 1.9.3, we model the scenario where the platform requires the dispute fee to be paid by both parties in order for the dispute case to be handled. In this case, after the freelancer initiates the dispute, the client decides whether to participate in the dispute by paying the dispute fee. If the client also pays the dispute fee, the dispute case will be evaluated. However, if the client decides not to pay the dispute fee, the freelancer will be automatically awarded a "win" and the client will then have to pay the freelancer. We find that the decentralized dispute system still dominates the centralized dispute system when the freelancer's skill level is sufficiently high. Thus, our main insight remains robust when the platform is allowed to choose which dispute fee structure to use under each dispute system. Moreover, we find that when the freelancer's skill level is only moderately high, the platform's optimal strategy is to combine the decentralized dispute system with the double-sided dispute fee structure. This indicates that platforms that intend to adopt the decentralized dispute system can use the double-sided dispute fee structure as a transitional step when the freelancers' skill levels are not sufficiently high, and switch to the single-sided dispute fee structure when the freelancers become more proficient.

### 1.7.4 Task Failure

In Section 1.9.4, we generalize the model by incorporating the risk of task failure. We find that the decentralized dispute system dominates the centralized dispute system when the risk of task failure is sufficiently low. When the risk of task failure is high, the platform's bias to rule in favor of the freelancer creates a cloak of certainty over the task outcome and incentivizes more freelancers to participate. This makes the centralized dispute system preferred by the platform. Moreover, the decentralized dispute system is more likely to be the preferred system if the freelancer is higher-skilled. Thus, our previous finding that the decentralized dispute system performs better with higher-skilled freelancers continues to hold.

### 1.7.5 Differential Subjectivity between Platform and Voters

In Section 1.9.5, we consider a model extension that allows the centralized dispute system to be associated with a lower degree of subjectivity in dispute judgment compared to the decentralized dispute system. This captures the scenario where the platform's dispute team members may be less subjective in quality evaluation because they are professionally trained. We find that as long as the degree of subjectivity is not too different between the two systems, our previous results continue to hold exactly and the platform should prefer the decentralized dispute system when the freelancer's skill level is sufficiently low. Moreover, the decentralized dispute system can be the preferred system even for lower-skilled freelancers when it substantially increases the degree of subjectivity in dispute judgment from that under the centralized dispute system.

### 1.7.6 Client's Reputation Loss

In Section 1.9.6, we extend the model by assuming that the client incurs a reputation loss if she rejects the freelancer's work and the freelancer files a dispute. The client's reputation loss is assumed to be proportional to the quality of the freelancer's work, to reflect the fact that a freelancer with a higher-quality work is more likely to view the client as unfair when being rejected, and hence is more likely to leave a negative review for the client. We find that the decentralized dispute system still dominates the centralized dispute system when the freelancer's skill level is sufficiently high. Thus, our main insight remains robust even if the client incurs a reputation loss because of dispute.

### 1.7.7 Heterogeneous Freelancers

In Section 1.9.7, we extend our model to allow for a heterogeneous freelancer pool consisting of two types of freelancers with different skill levels. While the client can choose the contract price based on the type of freelancer she is contracting with, the platform needs to set the same dispute fee upfront. This extension serves as a robustness check for our main insight when the platform is no longer able to use a single dispute fee to extract surplus from all platform users. Through numerical analysis, we observe that the decentralized dispute system dominates the centralized dispute system if the proportion of high-type freelancers is sufficiently high, which indicates a higher average skill level of the freelancer pool and is consistent with our main insight. In addition, we observe that the degree of heterogeneity within the freelancer pool also impacts the platform's optimal dispute system. Specifically, the centralized dispute system tends to perform better when the freelancers are more diverse in their skill levels.

## 1.8 Conclusion and Discussion

Disputes are an inevitable part of projects that involve multiple parties, and any intermediary platform must take into account dispute management when designing its policies. In this paper, we analyze and compare two types of dispute resolution systems for online labor platforms: the centralized dispute system, where the platform serves as the arbitrator, and the decentralized dispute system, where a tribunal consisting of individual platform users votes on the dispute case. Our findings shed light on the value and implementation of the decentralized dispute system. We demonstrate that the critical value of decentralizing dispute resolution lies in the collective input of diverse opinions from individual users, which can result in a fairer resolution and eliminate any decision-making bias of the platform. However, realizing this value requires the platform to ensure the heterogeneity of voter opinions and the skill level of the freelancer pool.

While our evaluation of the decentralized dispute system focuses on its fairness perspective, there are other factors that platforms should consider when adopting this system, which are beyond the scope of our model. For example, platforms need to consider the implementation costs of the tribunal system, including the costs of setting up the architecture and incentivizing users to participate as voters. However, such investments may pay off in the long run as the decentralized dispute system can reduce the expenditure of resources that platforms would otherwise incur in compensating in-house adjudicators. Moreover, since the decentralized dispute system crowdsources dispute resolution from the public, it has the potential to handle an increasing number of disputes as the number of platform users grows, ensuring its scalability. In addition, the rapid expansion of gig platforms and their substantial autonomy to dictate users' contractual terms have recently prompted regulations aimed at limiting the platforms' sweeping authority (Herman 2017). By requiring platforms to relinquish more decision-making power to their users, the decentralized dispute system can help reduce negative connotations and enable platforms to retain their status as part of the "sharing economy" where certain commercial and labor laws may not apply.

It is worth noting that many emerging platforms are decentralized autonomous organizations deployed on the blockchain. While blockchain is often viewed as a convenience way to implement the decentralized dispute system due to its ability to automate payment transactions and ensure credibility of payments, it is not the only option available. Platforms can use any trust-based payment intermediary to implement the incentive scheme of the tribunal system. For example, Ortolani (2015) proposes a pre-authorization model using credit cards. Under this approach, a voter will be subject to a credit card preauthorization to participate in the tribunal. Once the voting is complete, the voters will be credited with the appropriate amount through the intermediary, in this case, the credit card system. This adjudication process resembles that used by the emerging platforms but does not require the use of blockchain. Moreover, some emerging platforms, such as Kleros and Jur, are third-party service providers that specialize in providing decentralized dispute resolution services. As a result, a centralized platform can outsource dispute resolution to such platforms and integrate their dispute system with its own to create a decentralized dispute system. Thus, a centralized platform does not need to fully decentralize its operations to adopt the decentralized dispute system.

Finally, we hope our work could trigger more future research to study the operational aspect of dispute management for gig platforms. For example, we have focused on the case where the skill level of the freelancer is known. One future research direction could be incorporating asymmetric information with regards to the freelancer's skill level. Moreover, we have focused on the type of dispute that is initiated by the freelancer when the client refuses to pay. There are other types of disputes that gig platforms may need to handle, such as user conduct on the platform or intellectual property right of online gig work. It would be interesting to examine whether a decentralized arbitration mechanism can work well for other types of disputes. Finally, it would be interesting to study the long-term reputational effects of decentralizing dispute resolution for gig platforms and empirically test the theoretical predictions of these effects.

## 1.9 Auxiliary Results

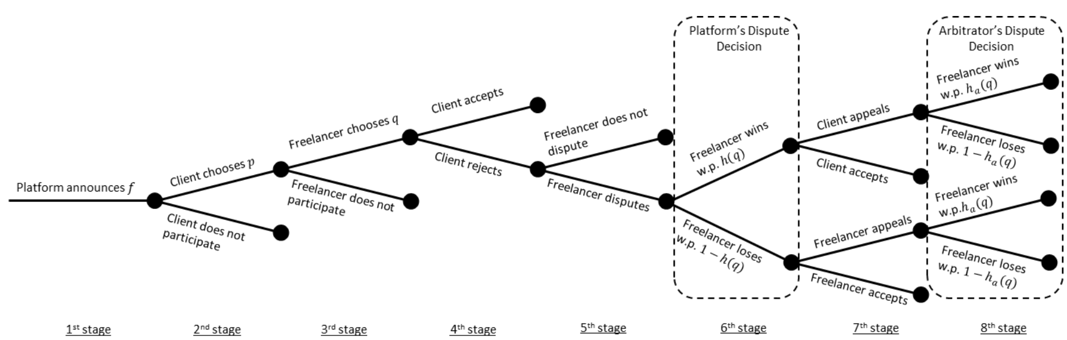
### 1.9.1 Third-Party Arbitration

#### Model

In our main model, we have assumed that the platform's dispute decision is binding under the centralized dispute system. In this section, we extend the model of the centralized dispute system to allow for a third-party arbitration if the platform users are not satisfied with the platform's decision. This mirrors the policy of some platforms (e.g., Upwork). In this case, after the platform has decided on the dispute case, both the freelancer and the client have the right to appeal the platform's decision, in which case a third-party arbitrator (e.g., the American Arbitration Association) will be involved to re-evaluate the dispute case and make a binding decision. We now examine this alternative centralized dispute system and compare it to the decentralized dispute system.

Figure 1.3 shows the sequence of events for the centralized dispute system with the option of third-party arbitration. Compared to the main model, the option of third-party arbitration introduces two more stages (Stages 7-8) in the game. After the platform's dispute decision is made, either the freelancer or the client can appeal the platform's decision (Stage 7). Note that since the winning party of the platform's decision always has the incentive to accept the platform's dispute decision, only the losing party of the platform's decision may choose to appeal. If the losing party appeals, the previous decision by the platform is overruled and the dispute case is resolved by the arbitrator (Stage 8). Let $h_a(q)$ denote the winning probability of the freelancer as a result of the arbitrator's decision.

Figure 1.3: Sequence of events for the centralized dispute system with third-party arbitration.



Similar to the platform, the arbitrator chooses its threshold $k_a$ to evaluate the freelancer's work, and receives an independent random signal of the freelancer's work, $x_a = q + \sigma\epsilon$. Hence, the third-party arbitrator will rule in favor of the freelancer if $x_a \geq k_a$ and rule in favor of the client if $x_a < k_a$. The arbitrator's dispute decision takes into consideration both the industry standard and the decision of the platform. Correspondingly, it incurs a weighted quadratic loss of $-\zeta_y(k_a - y)^2 - \zeta_k(k_a - k)^2$, where $\zeta_y$ and $\zeta_k$ represent the weights placed on the deviation from the industry standard and the platform's standard, respectively. We further define $\tau = \frac{\zeta_k}{\zeta_y + \zeta_k}$ as the degree of incentive alignment between the arbitrator and the platform. A higher $\tau$ indicates that the arbitrator has more shared interest with the platform and hence is more likely to make the same dispute decision as the platform. Thus, this model captures the platform's influence over the third-party arbitrator through the parameter $\tau$. We assume that the platform pays the arbitrator a fixed fee to guarantee that the arbitrator participates. This fixed fee is considered as a sunk cost and ignored from the model.

We next derive the platform's optimal strategy under the centralized dispute system with the option of third-party arbitration, and compare it to the decentralized dispute system. We use an additional subscript of $t$ to represent the equilibrium of the case with third-party arbitrator. We first consider the scenario where the option of third-party arbitration is covered by the dispute fee and the platform users do not need to pay an additional fee to appeal. In this case, the losing party always appeals, and the final dispute outcome is determined by the arbitrator. This case is analytically tractable and the results are presented in the next subsection. We then numerically examine the scenario where the platform users need to pay an additional fee to appeal (so that the losing party may find it too costly to appeal) and verify that our results are robust. All the proofs of results for this sub-section are relegated to Appendix A.6.

### Results

**Lemma 1.3** *(i) Under the centralized dispute system with third-party arbitration, the arbitrator's quality threshold is* $k_a^* = y - \frac{\gamma p \tau^2}{4\sigma\theta}$.

*(ii) The probability of the freelancer winning the dispute is*

$$h_a^*(q) = \begin{cases} 0 & \text{if } q \leq k_a^* - \sigma, \\ \frac{q-y+\sigma}{2\sigma} + \frac{\gamma p \tau^2}{8\sigma^2\theta} & \text{if } k_a^* - \sigma < q < k_a^* + \sigma, \\ 1 & \text{if } q \geq k_a^* + \sigma. \end{cases}$$

*which is increasing in* $q$ *and* $\tau$.

Lemma 1.3 shows that the arbitrator's quality threshold $k_a^*$ is always lower than the industry standard $y$, and is dependent on the degree of the arbitrator's incentive alignment with the platform $\tau$. An arbitrator whose incentive is more aligned with the platform (i.e., $\tau$ is higher) will set a quality threshold that is closer to the platform's quality standard in Lemma 1.1 to increase the winning probability of the freelancer. On the contrary, an arbitrator whose incentive is less aligned with the platform (i.e., $\tau$ is lower) will set a quality threshold that is closer to the industry standard.

**Proposition 1.4** *When third-party arbitration is used, the following occurs in equilibrium under the centralized dispute system:*

*(i) There exist two thresholds,* $\bar{\alpha}_{ct}$ *and* $\underline{\alpha}_{ct}$ *(where* $\bar{\alpha}_{ct} \geq \underline{\alpha}_{ct}$*), such that contracting occurs if and only if* $\alpha \leq \bar{\alpha}_{ct}$*, and given that contracting occurs, dispute occurs if* $\underline{\alpha}_{ct} < \alpha \leq \bar{\alpha}_{ct}$ *and does not occur if* $\alpha \leq \underline{\alpha}_{ct}$.

*(ii) The platform's equilibrium utility is* $\Pi_t^* = \frac{4\gamma\sigma\theta(y+\sigma)(\zeta_y+\zeta_k)^2}{\gamma\zeta_k^2+4\sigma\theta(\zeta_y+\zeta_k)^2}$ *if* $\alpha \leq \underline{\alpha}_{ct}$ *and* $\Pi_t^* = \frac{1}{4\alpha(\gamma\alpha\zeta_k^2+(1-\gamma)\theta(\zeta_y+\zeta_k)^2)^2}\Big[\theta(\zeta_y+\zeta_k)^2(2\alpha(y-\sigma)+(1-\gamma))\Big(-2\gamma^2\alpha^2(y-\sigma)\zeta_k^2-\alpha(1-\gamma)\Big(\zeta_k^2(\gamma(\gamma+2\sigma\theta-2)+2(1-\gamma)\theta y-2\sigma\theta)+4(1-\gamma)\theta\zeta_k\zeta_y(y-\sigma)+2(1-\gamma)\theta\zeta_y^2(y-\sigma)\Big)-(1-\gamma)^2(\gamma+1)\theta(\zeta_y+\zeta_k)^2\Big)\Big]$ *if* $\underline{\alpha}_{ct} < \alpha \leq \bar{\alpha}_{ct}$.

*(iii) Dispute is prevented in fewer cases (i.e.,* $\underline{\alpha}_{ct} \leq \underline{\alpha}_c$*) and contracting occurs in fewer cases (i.e.,* $\bar{\alpha}_{ct} \leq \bar{\alpha}_c$*).*

Proposition 1.4 shows that the equilibrium structure of the centralized dispute system remains unchanged if the platform users are able to appeal the platform's decision. Consistent with Proposition 1.1, contracting occurs without dispute if the freelancer's skill level is high, contracting occurs with dispute if the freelancer's skill level is medium, and contracting does not occur if the freelancer's skill level is low. However, the option of third-party arbitration causes dispute to be prevented in fewer cases (i.e., $\underline{\alpha}_{ct} \leq \underline{\alpha}_c$) and contracting to occur in fewer cases (i.e., $\bar{\alpha}_{ct} \leq \bar{\alpha}_c$). This is because the third-party arbitration reduces the bias in the platform's dispute resolution and makes the quality standard more stringent. As a result, the client becomes less likely to accept the freelancer's work, and the lower-skilled freelancers are weeded out as it becomes more difficult to meet the quality standard. We next compare the centralized dispute system with the option of third-party arbitration to the decentralized dispute system, to test the robustness of our main insight regarding when the platform should decentralize dispute resolution.

**Theorem 1.5** *Suppose* $\gamma \leq \frac{1}{3}$ *and* $\sigma \leq y$*. When third-party arbitration is used under the centralized dispute system, there exists a threshold* $\bar{\alpha}_t$*, which is increasing in* $\tau$*, such that the platform's equilibrium utility is higher under the decentralized dispute system (i.e.,* $\Pi^+ \geq \Pi_t^*$*) if* $\alpha \leq \bar{\alpha}_t$*, and is lower under the decentralized dispute system (i.e.,*

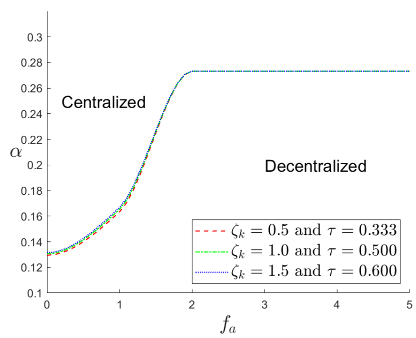
$\Pi^+ < \Pi_t^*$) *if* $\alpha > \bar{\alpha}_t$.

Theorem 1.5 shows, under the same conditions as in Theorem 1.3, that the decentralized dispute system still dominates the centralized dispute system if and only if the freelancer's skill level is sufficiently high (i.e., $\alpha \leq \bar{\alpha}_t$). Although third-party arbitration increases the quality standard under the centralized dispute system, the quality standard does not increase beyond the level under the decentralized dispute system which corresponds to the industry standard that is uninfluenced by the platform. Thus, the impact of decentralizing dispute resolution on the freelancer's quality-improving incentive remains qualitatively the same, and the result in Theorem 1.5 is consistent with that in Theorem 1.3.

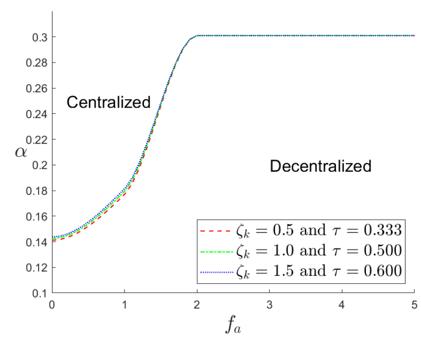
Moreover, Theorem 1.5 shows that the threshold $\bar{\alpha}_t$ is increasing in $\tau$. This indicates that if the arbitrator's incentive is more aligned with the platform (i.e., $\tau$ increases), the decentralized dispute system dominates the centralized dispute system in more cases (i.e., $\bar{\alpha}_t$ increases). Recall that when the freelancer's skill level is sufficiently high, decentralizing dispute resolution to a independent tribunal with no conflicts of interest creates value by removing the decision-making bias in the platform's dispute resolution. The option of third-party arbitration allows the centralized dispute system to achieve a similar (but less significant) value. However, the value will be more limited if the third-party arbitrator's incentive is more aligned with the platform, so that its arbitration is more influenced by the platform's bias. This implies that if third-party arbitration is value-adding, the platform should prefer an arbitrator that is more neutral and uninfluenced by its own decision-making protocol. However, even though a neutral third-party arbitrator exists, the platform may face challenges in convincing its users that the arbitrator is impartial. This is because the platform users may worry about potential conflicts of interest between the platform and any arbitrator it employs. Fully decentralizing dispute resolution to individual platform users removes the need for the platform to commit to a fairer dispute resolution, since the decision-making process is entirely entrusted to independent parties with no conflicts of interest.

Figure 1.4: The platform's optimal dispute system with third-party arbitration.

(a) $\theta = 0.01$, $\gamma = 0.3$, $y = 3$, $\sigma = 4$ and $\zeta_y = 1$




(b) $\theta = 0.01$, $\gamma = 0.3$, $y = 5$, $\sigma = 4$ and $\zeta_y = 1$




While we have so far assumed that it is costless for the platform users to appeal the platform's decision, to verify the robustness of our results with respect to the cost to appeal, we analyze the case where the platform users have to pay an arbitration fee, $f_a$, in addition to the dispute fee, if they want to appeal the platform's decision. $f_a$ is assumed to be exogenous and paid to the third-party arbitrator (rather than the platform). Because this case is not analytically tractable, we resort to a numerical analysis to examine the robustness of our results with the third-party arbitration fee. In Figure 1.4, we plot the platform's optimal dispute system as a function of $f_a$. From Figure 1.4, we continue to observe that the decentralized dispute system dominates the centralized dispute system (with the option of third-party arbitration) if and only if the freelancer's skill level is sufficiently high. Thus, consistent with Theorem 1.5, the platform's optimal strategy is characterized by a single threshold $\bar{\alpha}_t$. The results also reveal that when $f_a$ is sufficiently large, $\bar{\alpha}_t$ becomes a constant in $f_a$. This corresponds to the scenario where the platform users never appeal the platform's dispute decision as it is too costly to appeal. Moreover, each subfigure of Figure 1.4 shows a series of examples by varying the value of $\tau$. The results indicate that $\bar{\alpha}_t$ is increasing in $\tau$, which is once again consistent with Theorem 1.5. Thus, our insights are robust whether a third-party arbitration fee exists or not.

### 1.9.2 Price-Dependent Industry Standard

#### Model

In our main model, we have assumed that the industry standard is exogenous and the contracting parties cannot influence the industry standard. In this section, we allow the industry standard to be contingent on the contracting terms. Specifically, we let the industry standard be a linear function of the contract price $p$, such that $y = y_0 + \eta p$, where $y_0$ is the base industry standard, and $\eta > 0$ measures the sensitivity of the industry standard with respect to the contract price. Since $\eta > 0$, a higher contract price leads to a higher expectation of quality. We use an additional subscript of $p$ to represent the equilibrium of the case with price-dependent industry standard. All the proofs of results for this subsection are relegated to Appendix A.7.

#### Results

**Proposition 1.5** *When the industry standard is dependent on the contract price, the following occurs in equilibrium under the centralized dispute system:*

*(i) There exist two thresholds, $\bar{\alpha}_{cp}$ and $\underline{\alpha}_{cp}$ (where $\bar{\alpha}_{cp} \geq \underline{\alpha}_{cp}$), such that contracting occurs if and only if $\alpha \leq \bar{\alpha}_{cp}$, and given that contracting occurs, dispute occurs if $\underline{\alpha}_{cp} < \alpha \leq \bar{\alpha}_{cp}$ and does not occur if $\alpha \leq \underline{\alpha}_{cp}$.*

*(ii) The platform's equilibrium utility is $\Pi_p^* = \frac{4\gamma\sigma\theta(y_0+\sigma)}{\gamma+4\sigma\theta(1-\eta)}$ if $\alpha \leq \underline{\alpha}_{cp}$ and $\Pi_p^* = \frac{1}{4\alpha(\alpha(\gamma-4\sigma\theta\eta)-\gamma\theta+\theta)^2}\Big[\theta(2\alpha(y_0 - \sigma) + 1 - \gamma)\Big(2\alpha^2\gamma^2(\sigma - y_0) - \alpha(1 - \gamma)\left(\gamma^2 + 2\gamma(\sigma\theta - \theta y_0 - 1) + 2\theta(4\sigma\eta - \sigma + y_0)\right) + (1+\gamma)(1-\gamma)^2\theta\Big)\Big]$ if $\underline{\alpha}_{cp} < \alpha \leq \bar{\alpha}_{cp}$.*

**Proposition 1.6** *When the industry standard is dependent on the contract price, the following occurs in equilibrium under the decentralized dispute system:*

*(i) There exist two thresholds, $\bar{\alpha}_{dp}$ and $\underline{\alpha}_{dp}$ (where $\bar{\alpha}_{dp} \geq \underline{\alpha}_{dp}$), such that contracting occurs if and only if $\alpha \leq \bar{\alpha}_{dp}$, and given that contracting occurs, dispute occurs if $\underline{\alpha}_{dp} < \alpha \leq \bar{\alpha}_{dp}$ and does not occur if $\alpha \leq \underline{\alpha}_{dp}$.*

*(ii) The platform's equilibrium utility is $\Pi_p^+ = \frac{\gamma(y_0+\sigma)}{1-\eta}$ if $\alpha \leq \underline{\alpha}_{dp}$ and $\Pi_p^+ = \frac{(1-\gamma)(2\alpha(y_0-\sigma)+1-\gamma)(1-\gamma^2+2\alpha\gamma(y_0-\sigma)+2\alpha(\sigma-4\sigma\eta-y))}{4\alpha(-4\alpha\sigma\eta+1-\gamma)^2}$ if $\underline{\alpha}_{dp} < \alpha \leq \bar{\alpha}_{dp}$.*

Propositions 1.5 and 1.6 show that under both the centralized and decentralized dispute systems, allowing for a price-dependent industry standard does not change the equilibrium structure from the main model. Consistent with Propositions 1.1 and 1.3, contracting occurs without dispute if the freelancer's skill level is high, contracting occurs with dispute if the freelancer's skill level is medium, and contracting does not occur if the freelancer's skill level is low. We next test the robustness of our main insight regarding the platform's optimal strategy, by comparing the equilibrium outcomes characterized in Propositions 1.5 and 1.6. The results are summarized in Theorem 1.6.

**Theorem 1.6** *When the industry standard is dependent on the contract price, there* *exists a threshold $\bar{\sigma}_p$ such that if $\sigma \leq \bar{\sigma}_p$, the equilibrium quality level is always higher under the decentralized dispute system. Suppose $\gamma \leq \frac{1}{3}$ and $\sigma \leq \bar{\sigma}_p$. There exists a threshold $\bar{\eta}$, which is decreasing in $\alpha$, such that the platform's equilibrium utility is higher under the decentralized dispute system (i.e., $\Pi_p^+ \geq \Pi_p^*$) if and only if $\eta \leq \bar{\eta}$.*

Theorem 1.6 shows, under a slightly stronger condition than Theorem 1.3 ($\sigma \leq \bar{\sigma}_p$ guarantees that the equilibrium quality level is always higher under the decentralized dispute system), that the decentralized dispute system dominates the centralized dispute system if and only if the industry standard is less sensitive to the contract price (i.e., $\eta \leq \bar{\eta}$). When the industry standard is relatively insensitive to the contract price, the value of the decentralized dispute system in incentivizing quality improvement more efficiently persists. However, when the industry standard is too sensitive to the contract price, the freelancer is at a disadvantage as the client can influence a much higher expectation of the voters by increasing price slightly. This makes it more difficult for the freelancer (particularly a lower-skilled freelancer) to participate. In this case, the platform's bias to rule in favor of the freelancer can temper the higher industry standard influenced by the client and protect more freelancers to participate.

Moreover, Theorem 1.6 shows that the threshold $\bar{\eta}$ is decreasing in $\alpha$. This indicates that the decentralized dispute system is more likely to be the preferred system (i.e., $\bar{\eta}$ is higher) if the freelancer is higher-skilled (i.e., $\alpha$ is smaller). Thus, our previous finding that the decentralized dispute system performs better with higher-skilled freelancers continues to hold.

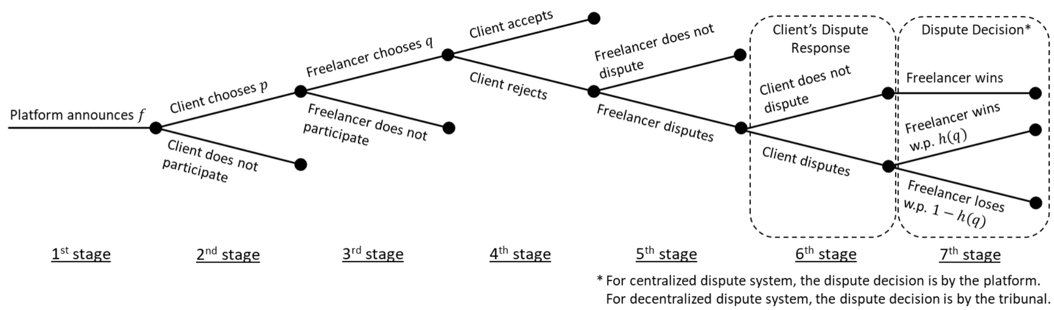
### 1.9.3 Double-Sided Dispute Fees

#### Model

In our main model, we have considered the case where the dispute will be initiated if the freelancer pays the dispute fee. Such a single-sided dispute fee structure is commonly used by online labor platforms (e.g., PeoplePerHour). Meanwhile, there are also online labor platforms that require the dispute fee to be paid by both parties in order for the dispute to be initiated. For example, Freelancer.com gives a four-day allowance for the other party to pay the dispute fee, before automatically closing the dispute in favor of the party that has initiated the dispute resolution by paying the dispute fee (see Figure A.4 in Appendix A.1 for the dispute resolution process of Freelancer.com). While the double-sided dispute fee structure is not as commonly used as the single-sided dispute fee structure, we are interested in understanding whether platforms can further benefit from switching to the double-sided dispute fee structure when they adopt the decentralized dispute system.

In this section, we model the scenario of the platform charging dispute fees to both the freelancer and the client. Under this model, if the freelancer initiates the dispute by paying the dispute fee and the client follows up to participate in the dispute by also paying the dispute fee, the dispute case will be evaluated. However, if the freelancer initiates the dispute but the client decides not to pay the dispute fee, the freelancer will be automatically awarded a "win" and the client will then have to pay the freelancer. The sequence of events with double-sided dispute fees is depicted in Figure 1.5. Note that compared to the main model, there is an additional Stage 6, where the client has to decide on whether to pay the dispute fee if the client has previously rejected the freelancer's work and the freelancer has initiated the dispute. We use an additional subscript of $d$ to represent the equilibrium of the case with double-sided dispute fees. All the proofs of results for this sub-section are relegated to Appendix A.8.

Figure 1.5: Sequence of events for the case with double-sided dispute fees.




### Results

**Proposition 1.7** *When the platform charges double-sided dispute fees, the following occurs in equilibrium under the centralized dispute system:*

*(i) There exist two thresholds, $\bar{\alpha}_{cd}$ and $\underline{\alpha}_{cd}$ (where $\bar{\alpha}_{cd} \geq \underline{\alpha}_{cd}$), such that contracting occurs if and only if $\alpha \leq \bar{\alpha}_{cd}$, and given that contracting occurs, dispute occurs if $\underline{\alpha}_{cd} < \alpha \leq \bar{\alpha}_{cd}$ and does not occur if $\alpha \leq \underline{\alpha}_{cd}$.*

*(ii) The platform's equilibrium utility is $\Pi_d^* = \gamma \frac{y-\sigma+2\gamma\sigma}{1+\frac{\gamma}{4\sigma\theta}}$ if $\alpha \leq \underline{\alpha}_{cd}$ and $\Pi_d^* = \frac{\theta(2(2-\gamma)\alpha(y-\sigma)+(1-\gamma))}{\alpha((3-\gamma)(1-\gamma)\theta+2(2-\gamma)\gamma\alpha)^2}((-2\alpha^2(2-\gamma)\gamma^2(y-\sigma)+\alpha(1-\gamma)(\gamma(4-3\gamma)-2(3-\gamma)\gamma\sigma\theta-2(2-\gamma)(1-\gamma)\theta y+4\sigma\theta)+2(1-\gamma)^2\theta)$ if $\underline{\alpha}_{cd} < \alpha \leq \bar{\alpha}_{cd}$.*

*(iii) Suppose $\sigma \leq y$. Dispute is prevented in more cases (i.e., $\underline{\alpha}_{cd} \geq \underline{\alpha}_{c}$) and contracting occurs in more cases (i.e., $\bar{\alpha}_{cd} \geq \bar{\alpha}_{c}$).*

**Proposition 1.8** *When the platform charges double-sided dispute fees, the following occurs in equilibrium under the decentralized dispute system:*

*(i) There exist two thresholds, $\bar{\alpha}_{dd}$ and $\underline{\alpha}_{dd}$ (where $\bar{\alpha}_{dd} \geq \underline{\alpha}_{dd}$), such that contracting occurs if and only if $\alpha \leq \bar{\alpha}_{dd}$, and given that contracting occurs, dispute occurs if $\underline{\alpha}_{dd} < \alpha \leq \bar{\alpha}_{dd}$ and does not occur if $\alpha \leq \underline{\alpha}_{dd}$.*

*(ii) The platform's equilibrium utility is $\Pi_d^+ = \gamma(y - \sigma + 2\gamma\sigma)$ if $\alpha \leq \underline{\alpha}_{dd}$ and $\Pi_d^+ = \frac{2(-(2-\gamma)\alpha(y-\sigma)+1)(2(2-\gamma)\alpha(y-\sigma)+1-\gamma)}{\alpha(3-\gamma)^2}$ if $\underline{\alpha}_{dd} < \alpha \leq \bar{\alpha}_{dd}$.*

*(iii) Suppose $\sigma \leq y$. Dispute is prevented in more cases (i.e., $\underline{\alpha}_{dd} \geq \underline{\alpha}_{d}$) and contracting occurs in more cases (i.e., $\bar{\alpha}_{dd} \geq \bar{\alpha}_{d}$).*

Propositions 1.7 and 1.8 show that under both the centralized and decentralized dispute systems, charging double-sided dispute fees does not change the equilibrium structure from the main model. Consistent with Propositions 1.1 and 1.3, contracting occurs without dispute if the freelancer's skill level is high, contracting occurs with dispute if the freelancer's skill level is medium, and contracting does not occur if the freelancer's skill level is low. However, because the double-sided dispute fee structure makes the dispute more costly for the client, she is now willing to accept the work of more freelancers (as shown by Propositions 1.7 and 1.8, $\underline{\alpha}_{cd} \geq \underline{\alpha}_{c}$ and $\underline{\alpha}_{dd} \geq \underline{\alpha}_{d}$). With double-sided dispute fees, if the client rejects the freelancer's work and the freelancer ends up winning the dispute, the client would lose an additional dispute fee on top of the contract price. Thus, there is a greater range of $\alpha$ such that the client does not reject the freelancer's work (i.e., $\underline{\alpha}_{c} < \alpha \leq \underline{\alpha}_{cd}$ or $\underline{\alpha}_{d} < \alpha \leq \underline{\alpha}_{dd}$). On the other hand, when the freelancer is lower-skilled (i.e., $\alpha > \underline{\alpha}_{cd}$ or $\alpha > \underline{\alpha}_{dd}$), dispute still occurs. In this case, the client will find it worthwhile to engage in a dispute even though she may have to pay the dispute fee, as a lower-skilled freelancer tends to have a lower chance of winning the dispute. Nevertheless, because the double-sided dispute fee structure gives an advantage to the freelancer, we find, under the condition of $\sigma \leq y$ (which is a condition also used in Theorem 1.3), that more freelancers are willing to participate when the platform charges double-sided dispute fees (as shown by Propositions 1.7 and 1.8, $\bar{\alpha}_{cd} \geq \bar{\alpha}_c$ and $\bar{\alpha}_{dd} \geq \bar{\alpha}_d$). We next derive the platform's optimal strategy when it can choose the optimal dispute fee structure along with the type of the dispute system to adopt. The results are summarized in Theorem 1.7.

**Theorem 1.7** *There exists a threshold $\tilde{\sigma}$ such that if $\sigma \leq \tilde{\sigma}$, the equilibrium quality level is always higher under the decentralized dispute system. Suppose $\gamma \leq \frac{1}{3}$ and $\sigma \leq \tilde{\sigma}$. When the platform can choose between single-sided or double-sided dispute fees, there exist a threshold $\tilde{\alpha}_d$ such that the platform's equilibrium utility is higher under the decentralized dispute system if $\alpha \leq \tilde{\alpha}_d$. Furthermore, there exists a threshold $\tilde{\alpha}_{dd}$ such that if $\tilde{\alpha}_{dd} < \alpha \leq \tilde{\alpha}_d$, the optimal strategy is to use the decentralized dispute system with double-sided dispute fees.*

Theorem 1.7 shows, under a slightly stronger condition than Theorem 1.3 ($\sigma \leq \tilde{\sigma}$ guarantees that the equilibrium quality level is always higher under the decentralized dispute system), that the decentralized dispute system dominates the centralized dispute system if and only if the freelancer's skill level is sufficiently high (i.e., $\alpha \leq \tilde{\alpha}_d$). Thus, our main insight remains robust when the platform is allowed to choose which dispute fee structure to use under each dispute system.

Theorem 1.7 further shows that when the freelancer's skill level is moderately high (i.e., $\tilde{\alpha}_{dd} < \alpha \leq \tilde{\alpha}_d$, where the additional subscript of $d$ in $\tilde{\alpha}_{dd}$ denotes the double-sided dispute fee structure), the platform's optimal strategy is to combine the decentralized dispute system with the double-sided dispute fee structure. When the freelancer's skill level is very high, dispute does not occur in equilibrium under the decentralized dispute system. Nevertheless, with a double-sided dispute fee structure, it becomes more costly for the client to reject the freelancer's work because the client would have to pay the dispute fee if the freelancer initiates the dispute afterwards. Thus, the freelancer is able to choose a lower quality level while making sure that the client is unable to reject his work. Consequently, the client offers a lower contract price and the platform's utility is lower. Hence, the decentralized dispute system works better with a single-sided dispute fee in this case. However, when the freelancer's skill level is only moderately high (i.e., $\tilde{\alpha}_{dd} < \alpha \leq \tilde{\alpha}_d$), dispute occurs under the decentralized dispute system. In this case, by charging the dispute fee to both sides of the market, the platform has one additional source of revenue (i.e., the dispute fee charged to the client) over which it has direct control and becomes even less reliant on the commission revenue over which it only has indirect control. Therefore, the decentralized dispute system works better with double-sided dispute fees in this case.

Our results indicate that platforms can use double-sided dispute fees to cater to the freelancer market with intermediate skill levels when adopting the decentralized dispute system. This has important implications for platforms as platforms that intend to adopt the decentralized dispute system can consider first using the double-sided dispute fee structure as a transitional step when the freelancers' skill levels are not sufficiently high. However, as the freelancers become more proficient, the single-sided dispute fee structure can be considered.

### 1.9.4 Task Failure

#### Model

In our main model, we have considered the case where the freelancer does not face any risk in completing the task. Such a setting would correspond to tasks whose outcomes are predictable. For example, for a house-cleaning task, the more effort incurred by the freelancer can be directly translated into a cleaner house. Nevertheless, there are other types of tasks that can have less predictable outcomes even though the freelancer has incurred the effort. For example, tasks that involve programming (e.g., software development) are associated with a chance of project failure. Even though the freelancer has spent the time needed to program the software, a coding error can cause the software to fail to perform as expected, making it unusable for the client. In general, tasks that are more complex in nature can be more susceptible to the risk of failure. In this section, we generalize the model by incorporating the risk of task failure, to gain an understanding of how the platform's optimal dispute system can be influenced by the type of task involved.

To model task failure, we introduce a probability $\beta \in (0, 1]$ such that the freelancer's realized quality, denoted as $\tilde{q}$, is equal to his effort level $q$ with probability $\beta$ and zero with probability $1 - \beta$. Thus, $\beta$ measures the chance of task failure, and a smaller $\beta$ corresponds to a higher degree of risk arising from task failure. The dispute decision is based on the realized task outcome, for both the centralized and decentralized dispute systems. The task outcome is realized at the end of Stage 3 in the sequence of events shown in Figure 1.1 (i.e., after the freelancer chooses the quality level, but before the client decides whether to accept or reject the freelancer's work). We use an additional subscript of $f$ to represent the equilibrium of the case with task failure. All the proofs of results for this sub-section are relegated to Appendix A.9.

### Results

**Proposition 1.9** *When the freelancer faces the risk of task failure, the following occurs in equilibrium under the centralized dispute system:*

*(i) There exist two thresholds, $\bar{\alpha}_{cf}$ and $\underline{\alpha}_{cf}$ (where $\bar{\alpha}_{cf} \geq \underline{\alpha}_{cf}$), such that contracting occurs if and only if $\alpha \leq \bar{\alpha}_{cf}$, and given that contracting occurs, dispute occurs if $\underline{\alpha}_{cf} < \alpha \leq \bar{\alpha}_{cf}$ and does not occur if $\alpha \leq \underline{\alpha}_{cf}$.*

*(ii) The platform's equilibrium utility is $\Pi_f^* = \beta\gamma\frac{4\sigma\theta(y+\sigma)}{\gamma+4\sigma\theta}$ if $\alpha \leq \underline{\alpha}_{cf}$ and $\Pi_f^* = \frac{\beta\theta(2\alpha(y-\sigma)+\beta(1-\gamma))\left(-2\gamma^2\alpha^2(y-\sigma)+\beta(1-\gamma)\alpha((2-\gamma)\gamma-2\gamma\sigma\theta-2(1-\gamma)\theta y+2\sigma\theta)+\beta^2(1+\gamma)(1-\gamma)^2\theta\right)}{4\alpha(\gamma\alpha+\beta(1-\gamma)\theta)^2}$ if $\underline{\alpha}_{cf} < \alpha \leq \bar{\alpha}_{cf}$.*

*(iii) Dispute is prevented in fewer cases (i.e., $\underline{\alpha}_{cf} \leq \underline{\alpha}_c$) and contracting occurs in fewer cases (i.e., $\bar{\alpha}_{cf} \leq \bar{\alpha}_c$).*

**Proposition 1.10** *When the freelancer faces the risk of task failure, the following occurs in equilibrium under the decentralized dispute system:*

*(i) There exist two thresholds, $\bar{\alpha}_{df}$ and $\underline{\alpha}_{df}$ (where $\bar{\alpha}_{df} \geq \underline{\alpha}_{df}$), such that contracting occurs if and only if $\alpha \leq \bar{\alpha}_{df}$, and given that contracting occurs, dispute occurs if $\underline{\alpha}_{df} < \alpha \leq \bar{\alpha}_{df}$ and does not occur if $\alpha \leq \underline{\alpha}_{df}$.*

*(ii) The platform's equilibrium utility is $\Pi_f^+ = \beta\gamma(y+\sigma)$ if $\alpha \leq \underline{\alpha}_{df}$ and $\Pi_f^+ = \frac{(2\alpha(y-\sigma)+\beta(1-\gamma))(-2\alpha(y-\sigma)+\beta(1+(2\beta-1)\gamma))}{4\alpha\beta}$ if $\underline{\alpha}_{df} < \alpha \leq \bar{\alpha}_{df}$.*

*(iii) Dispute is prevented in fewer cases (i.e., $\underline{\alpha}_{df} \leq \underline{\alpha}_d$) and contracting occurs in*

*fewer cases (i.e., $\bar{\alpha}_{df} \le \bar{\alpha}_d$).*

Propositions 1.9 and 1.10 show that for both the centralized and decentralized dispute systems, incorporating the risk of task failure does not change the equilibrium structure from the main model. Consistent with Propositions 1.1 and 1.3, contracting occurs without dispute if the freelancer's skill level is high, contracting occurs with dispute if the freelancer's skill level is medium, and contracting does not occur if the freelancer's skill level is low. However, the risk of task failure causes the $\alpha$ thresholds to be smaller under both the centralized and decentralized dispute systems (i.e., $\underline{\alpha}_{cf} \le \underline{\alpha}_c$ and $\bar{\alpha}_{cf} \le \bar{\alpha}_c$, and $\underline{\alpha}_{df} \le \underline{\alpha}_d$ and $\bar{\alpha}_{df} \le \bar{\alpha}_d$). When the risk of task failure is higher, it is more costly for the freelancer to meet the quality standard set by the platform and the tribunal. The freelancer has to manage both the probability of winning the dispute and the additional risk arising from task failure. As such, only higher-skilled freelancers are able to stand a sufficient chance of winning the dispute and are willing to participate (i.e., $\bar{\alpha}_{cf} \le \bar{\alpha}_c$ and $\bar{\alpha}_{df} \le \bar{\alpha}_d$). Furthermore, the increased difficulty in meeting the quality standard under both systems also makes it more costly for the freelancer to avoid the dispute. Hence, only higher-skilled freelancers will be able to avoid the dispute under both dispute systems (i.e., $\underline{\alpha}_{cf} \le \underline{\alpha}_c$ and $\underline{\alpha}_{df} \le \underline{\alpha}_d$). The changes in the $\alpha$ thresholds indicate that the risk of task failure can have an impact on the platform's utility. By comparing the equilibrium outcomes under the two systems, we can characterize when the decentralized dispute system should be preferred by the platform, which is shown in Theorem 1.8.

**Theorem 1.8** *When the freelancer faces the risk of task failure, if $\sigma \le \bar{\sigma}$, the equilibrium quality level is always higher under the decentralized dispute system. Suppose*

*$\gamma \leq \frac{1}{3}$ and $\sigma \leq \bar{\sigma}$. There exists a threshold $\bar{\beta}$, which is increasing in $\alpha$, such that the platform's equilibrium utility is higher under the decentralized dispute system (i.e., $\Pi_f^+ \geq \Pi_f^*$) if and only if $\beta \geq \bar{\beta}$.*

Theorem 1.8 shows, under the same conditions as in Theorem 1.3, that the decentralized dispute system dominates the centralized dispute system if and only if the risk of task failure is sufficiently low (i.e., $\beta \geq \bar{\beta}$). Recall that under the centralized dispute system, the platform tends to rule in favor of the freelancer because it can earn the commission fee if the freelancer wins the dispute. When the risk of task failure is high, the platform can use this lever in a similar way and adapt to a lower standard. In this way, the platform's bias helps to create a cloak of certainty over the task outcome to help the freelancer to participate, especially when the risk of task failure is higher. This makes the centralized dispute system the preferred system for the platform in this case. On the other hand, under the decentralized dispute system, the platform relegates dispute resolution to the tribunal and cannot cater the tribunal's standard to the degree of risk faced by the freelancer. Thus, the freelancer would face more risk compared to the centralized dispute system and hence would be less willing to participate. However, when the risk of task failure is lower, the decentralized dispute system can maintain its value of incentivizing quality improvement more efficiently, and continues to be the preferred system.

Moreover, Theorem 1.8 shows that the threshold $\bar{\beta}$ is increasing in $\alpha$. This indicates that the decentralized dispute system is more likely to be the preferred system (i.e., $\bar{\beta}$ is lower) if the freelancer is higher-skilled (i.e., $\alpha$ is smaller). Thus, our previous finding that the decentralized dispute system performs better with higher-skilled freelancers continues to hold.

An inspection of the emerging platforms that are using the decentralized dispute systems shows that some of them are targeting tasks that are more complex in nature, and hence tend to have a higher risk of task failure (e.g., CryptoTask caters to programming tasks). However, our findings suggest that platforms should be cautious about outsourcing dispute resolution to the crowd when the task is associated with a higher risk of failure. Instead, keeping the dispute resolution centralized can be a better way to deal with the uncertainties caused by these tasks.

### 1.9.5 Differential Subjectivity between Platform and Voters

#### Model

In our main model, we have assumed that when a dispute occurs, the evaluators under both the centralized (i.e., the platform) and decentralized (i.e., the voters) dispute systems have the same degree of heterogeneity in terms of their subjective evaluation of the freelancer's work. The degree of subjectivity is measured by $\sigma$ for anyone who evaluates a dispute case. In this section, we consider a model extension that allows the members of the platform's dispute team to have a different degree of subjectivity, $\sigma_c$, than the voters, $\sigma_d$. Moreover, we assume that $\sigma_c \leq \sigma_d$, so that the degree of subjectivity is lower under the centralized dispute system. This is based on the assumption that the platform's dispute team members may be less subjective in quality evaluation because they are professionally trained. We use an additional subscript of $s$ to represent the equilibrium of the case with different degrees of subjectivity. All the proofs of results for this sub-section 1.9.5 are relegated to Appendix A.10.

### Results

**Theorem 1.9** *Suppose* $\gamma \leq \frac{1}{3}$, $\sigma_c \leq y$ *and* $\sigma_d \leq y$. *When the platform's dispute team has a lower degree of subjectivity than the voters, there exists a threshold* $\bar{\alpha}_s$ *such that the platform's equilibrium utility is higher under the decentralized dispute system (i.e.,* $\Pi_s^+ \geq \Pi_s^*$*) if* $\alpha \leq \bar{\alpha}_s$. *Moreover, there exists a threshold* $Z \leq 1$ *such that if* $\sigma_c \geq Z\sigma_d$, *the platform's equilibrium utility is higher under the centralized dispute system (i.e.,* $\Pi_s^* > \Pi_s^+$*) if* $\alpha > \bar{\alpha}_s$.

Theorem 1.9 compares the two dispute systems under similar conditions as in Theorem 1.3. Note that the $\sigma \leq y$ condition in Theorem 1.3 is replaced by $\sigma_c, \sigma_d \leq y$ as the degree of subjectivity is different under the two dispute systems now. Theorem 1.9 first shows that the decentralized dispute system is the optimal system if the freelancer's skill level is sufficiently high (i.e., $\alpha \leq \bar{\alpha}_s$). This implies that our previous insight that the decentralized dispute system is more suitable when the freelancer pool is highly skilled remains valid, even if the decentralized dispute system is associated with a higher degree of subjectivity.

Moreover, Theorem 1.9 shows that as long as the degree of subjectivity is not too different between the two systems (i.e., $\sigma_c \geq Z\sigma_d$), the centralized dispute system is the optimal system if the freelancer's skill level is not sufficiently high (i.e., $\alpha > \bar{\alpha}_s$). Thus, our previous results continue to hold exactly and the platform's optimal strategy is characterized by a single threshold on $\alpha$, below which the decentralize dispute system dominates the centralized dispute system, and vice versa.

However, if the degree of subjectivity is too different between the two systems (i.e., $\sigma_c$ is too small), the centralized dispute system may not be guaranteed to be the optimal system for a lower-skilled freelancer. A $\sigma_c$ that is too small can exacerbate the consequence of the platform's decision-making bias. To see this, consider the extreme case of $\sigma_c = 0$, where the dispute outcome under the centralized dispute system becomes deterministic. In this case, given the platform's bias, the freelancer will win the dispute with certainty, and the client will be unable to win the dispute. As a result, the client has to accept any work from the freelancer, and the freelancer has no incentive to improve quality. This outcome removes the client's incentive to participate in the first place and contracting does not occur. Thus, the centralized dispute system is dominated by the decentralized dispute system even for a lower-skilled freelancer. When $\sigma_c$ is positive but small, the effect described above can still be significant. Consequently, comparing the two dispute systems becomes more complex, as the value of the centralized dispute system for a lower-skilled freelancer can be countered by the aforementioned effect. Although the platform's optimal strategy cannot be fully characterized in this case, our results in this extension indicate that the decentralized dispute system can be preferred in more cases when it substantially increases the degree of subjectivity in dispute judgment from that under the centralized dispute system. Furthermore, our previous insights remain valid when the two dispute systems have similar degrees of subjectivity in dispute judgment.

### 1.9.6 Client's Reputation Loss

#### Model

In our main model, we have considered the case where the client does not incur any cost because of dispute. However, due to the review system that gig platforms typically offer, a client who frequently goes through disputes may suffer from a reputation loss in the long term. Having a dispute means that the client has rejected the freelancer's work while the freelancer disagrees and thinks his work quality is worthy of getting paid. Thus, the freelancer may be viewing the client as unfair and is likely to leave a negative review for the client, causing a reputation loss for the client. In this section, we test the robustness of our main insights by assuming that the client incurs a reputation loss of $\phi q$ if she rejects the freelancer's work and the freelancer files a dispute. Note that the client incurs the reputation loss only if the freelancer files a dispute, while if the freelancer does not file a dispute after his work is rejected, the client does not incur the reputation loss. The client's reputation loss is assumed to be proportional to the quality of the freelancer's work, to reflect the fact that a freelancer with a higher-quality work is more likely to view the client as unfair when being rejected, and hence is more likely to leave a negative review for the client. We use an additional subscript of $l$ to represent the equilibrium of the case with the client's reputation loss. All the proofs of results for this sub-section are relegated to Appendix A.11.

**Results**

**Proposition 1.11** *When the client incurs a reputation loss because of dispute, the following occurs in equilibrium under the centralized dispute system:*

*(i) There exist two thresholds,* $\bar{\alpha}_{cl}$ *and* $\underline{\alpha}_{cl}$ *(where* $\bar{\alpha}_{cl} \geq \underline{\alpha}_{cl}$*), such that contracting occurs if and only if* $\alpha \leq \bar{\alpha}_{cl}$*, and given that contracting occurs, dispute occurs if* $\underline{\alpha}_{cl} < \alpha \leq \bar{\alpha}_{cl}$ *and does not occur if* $\alpha \leq \underline{\alpha}_{cl}$*.*

*(ii) The platform's equilibrium utility is* $\Pi_l^* = \frac{4\gamma\sigma\theta(y+\sigma-2\phi\sigma)}{\gamma+4\sigma\theta}$ *if* $\alpha \leq \underline{\alpha}_{cl}$ *and* $\Pi_l^* = \frac{1}{4\alpha(\gamma\alpha+(1-\gamma)\theta)^2}\Big[\theta(2\alpha(y-\sigma)+(1-\gamma)(1-\phi))\Big(-2\gamma^2\alpha^2(y-\sigma)+(1-\gamma)\alpha((2-\gamma)\gamma(1-\phi)-2\gamma\sigma\theta-2(1-\gamma)\theta y+2\sigma\theta)+(1+\gamma)(1-\gamma)^2(1-\phi)\theta\Big)\Big]$ *if* $\underline{\alpha}_{cl} < \alpha \leq \bar{\alpha}_{cl}$*.*

*(iii) Dispute is prevented in more cases (i.e.,* $\underline{\alpha}_{cl} \geq \underline{\alpha}_{c}$*).*

**Proposition 1.12** *When the client incurs a reputation loss because of dispute, the following occurs in equilibrium under the decentralized dispute system:*

*(i) There exist two thresholds,* $\bar{\alpha}_{dl}$ *and* $\underline{\alpha}_{dl}$ *(where* $\bar{\alpha}_{dl} \geq \underline{\alpha}_{dl}$*), such that contracting occurs if and only if* $\alpha \leq \bar{\alpha}_{dl}$*, and given that contracting occurs, dispute occurs if* $\underline{\alpha}_{dl} < \alpha \leq \bar{\alpha}_{dl}$ *and does not occur if* $\alpha \leq \underline{\alpha}_{dl}$*.*

*(ii) The platform's equilibrium utility is* $\Pi_l^+ = \gamma(y+\sigma-2\phi\sigma)$ *if* $\alpha \leq \underline{\alpha}_{dl}$ *and* $\Pi_l^+ = \frac{(2\alpha(y-\sigma)+(1-\gamma)(1-\phi))(-2\alpha(y-\sigma)+(1+\gamma)(1-\phi))}{4\alpha}$ *if* $\underline{\alpha}_{dl} < \alpha \leq \bar{\alpha}_{dl}$*.*

*(iii) Dispute is prevented in more cases (i.e.,* $\underline{\alpha}_{dl} \geq \underline{\alpha}_{d}$*).*

Propositions 1.11 and 1.12 show that for both the centralized and decentralized dispute systems, incorporating the client's reputation loss does not change the equilibrium structure from the main model. Consistent with Propositions 1.1 and 1.3, contracting occurs without dispute if the freelancer's skill level is high, contracting occurs with dispute if the freelancer's skill level is medium, and contracting does not occur if the freelancer's skill level is low. Nevertheless, the client's reputation loss prevents dispute from occurring in more cases (i.e., $\underline{\alpha}_{cl} \geq \underline{\alpha}_c$ and $\underline{\alpha}_{dl} \geq \underline{\alpha}_d$). This result appeals to intuition as if the client incurs a higher cost of dispute, she is less likely to reject the freelancer's work. Thus, the client lowers her quality standard in deciding whether to reject the freelancer's work, and even lower-skilled freelancers are able to meet the client's standard. To understand whether the platform's optimal strategy will change as a result of the client's reputation loss, we next compare the equilibrium outcomes characterized in Propositions 1.11 and 1.12. The results are summarized in Theorem 1.10.

**Theorem 1.10** *When the client incurs a reputation loss because of dispute, there exists a threshold $\bar{\sigma}_l$ such that if $\sigma \leq \bar{\sigma}_l$, the equilibrium quality level is always higher under the decentralized dispute system. Suppose $\gamma \leq \frac{1}{3}$ and $\sigma \leq \bar{\sigma}_l$. There exists a threshold $\bar{\alpha}_l$ such that the platform's equilibrium utility is higher under the decentralized dispute system (i.e., $\Pi_l^+ \geq \Pi_l^*$) if and only if $\alpha \leq \bar{\alpha}_l$.*

Theorem 1.10 shows, under a slightly stronger condition than Theorem 1.3 ($\sigma \leq \bar{\sigma}_l$ guarantees that the equilibrium quality level is always higher under the decentralized dispute system), that the decentralized dispute system dominates the centralized dispute system if and only if the freelancer's skill level is sufficiently high (i.e., $\alpha \leq \bar{\alpha}_l$). Thus, our main insight remains robust even if the client incurs a reputation loss because of dispute.

### 1.9.7 Heterogeneous Freelancers

In this section, we consider a model extension where the freelancer pool can have heterogeneous skill levels. In particular, we assume that $\rho$ proportion of freelancers are high-type with skill level $\alpha_h$ and $1-\rho$ proportion are low-type with skill level $\alpha_l$, where $\alpha_l > \alpha_h$. Thus, a higher $\rho$ corresponds to a more skilled freelancer pool. With a heterogeneous freelancer pool, the client will choose the contract price based on which type of freelancer she is contracting with. However, the platform needs to set the same dispute fee upfront. Thus, it needs to consider the participation of each type of freelancers and it is possible for only one type of freelancers to participate in equilibrium. Due to limited tractability, we resort to a numerical analysis to examine when the platform should choose the decentralized dispute system with a heterogeneous freelancer pool. This extension serves as a robustness check for our main insight when the platform is no longer able to use a single dispute fee to extract the surplus from all platform users since it faces a heterogeneous freelancer pool.

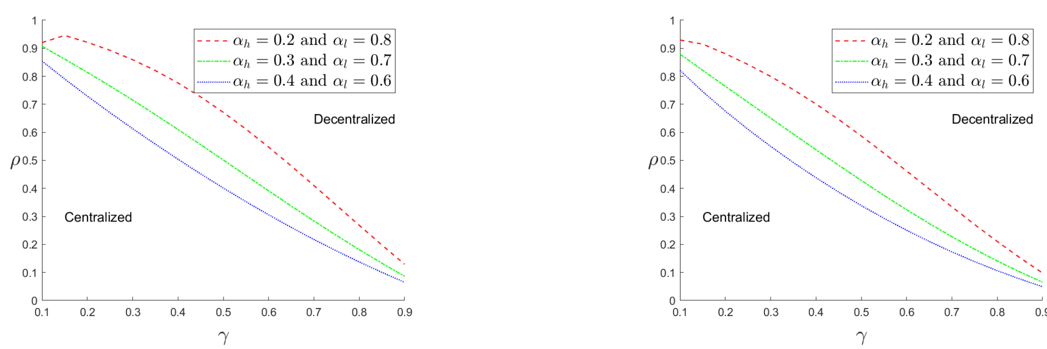
From our numerical analysis, we observe that if the proportion of high-type freelancers is sufficiently high (i.e., if $\rho$ is higher than a threshold $\bar{\rho}$), the decentralized dispute system dominates the centralized dispute system. This indicates that the platform should choose the decentralized dispute system when the average skill level of a heterogeneous freelancer pool is sufficiently high. Note that this is consistent with our main result in Theorem 1.3, where the decentralized dispute system should be chosen when the skill level of a homogeneous freelancer pool is sufficiently high. In Figure 1.6, we plot the threshold $\bar{\rho}$ that determines the platform's optimal dispute system, as a function of $\gamma$.

Furthermore, we also observe from Figure 1.6 that as the difference between

$\alpha_h$ and $\alpha_l$ increases while holding the average of the two skill levels constant, $\bar{\rho}$ tends to increase. This observation suggests that the degree of heterogeneity within the freelancer pool can also have an impact on the platform's optimal dispute system. In particular, the centralized dispute system tends to perform better when the freelancers are more diverse in their skill levels (i.e., $\alpha_l - \alpha_h$ is greater). In a more diverse freelancer pool, the lower-skilled freelancers are at a greater disadvantage and are less likely to survive under the decentralized dispute system given the higher quality standard set by the tribunal. However, under the centralized dispute system, the platform is able to shelter these lower-skilled freelancers by catering the quality standard towards them. This results in a larger revenue stream under the centralized dispute system. Therefore, even if the average skill level of the freelancer pool is high, the centralized dispute system may be a more suitable option if the freelancer pool is very diverse and the lower-skilled freelancers constitute the majority.

Figure 1.6: The platform's optimal dispute system with heterogeneous freelancers.

(a) $\theta = 0.1$, $y = 3$ and $\sigma = 3.5$ (b) $\theta = 0.1$, $y = 4$ and $\sigma = 3.5$



CHAPTER 2

**DO PREDICTIVE SCHEDULING LAWS WORK?**

## 2.1 Introduction

Firms in the service industry, such as retail stores or restaurants, have always been a tough place to work in. The service industry is known not only for the low pay as most of the workers have to survive based on the minimum wage, but also for the stressful environment due to the high work pace and the long hours (Marion 2018). Thus, there are many regulations targeting the service industry in order to improve the welfare of the workers, with a particular focus on the wages of the workers, such as the Fair Labor Standard Act. However, in addition to the low pay, there is one often overlooked problem faced by the workers, which is the erratic work schedules. Workers, particularly in the food and service industry, mainly work on a weekly work schedule. This is because the firms in such industries have a short planning horizon and they do not need the same number of workers on a consistent basis. Thus, the worker schedules may vary significantly from week to week. Some employees may even be placed on-call, without a fixed schedule or any guarantee of shifts. Thus, the hours for which an employee is scheduled to work or that the employee actually works may increase or decrease substantially from week-to-week.

The unpredictability in the schedules stems mainly from employee absenteeism and the adoption of just-in-time scheduling. The firms in the service industry are heavily dependent on the workers as their primary and are unable to provide the required service level if there are workers that are absent due to sickness or other family matters. It is then the usual practice of the firms to call on the remaining workers to take on additional shifts to cover for the absentees. The recent COVID pandemic even fueled employee absenteeism in the service industry (Torry 2022). Such a problem is exacerbated by the adoption of the just-in-time (JIT) scheduling. Almost every major retail and restaurant chains, such as Starbucks, have relied on the JIT scheduling software (Kantor 2014). JIT scheduling has helped the manufacturing industry save quite a lot of cost but when it is applied to the food and service industry, there are unintended consequences. This is because workers are seen as costs and not as assets. Managers are pressured to keep costs down and they are compensated based on the efficiency of their staffing (Marion 2018). Thus, they use as little labor as possible and only schedule for the workers if they are sure that the customers will show up. With the advent of new technology, the employee scheduling software is even able to plan for the optimal workforce by taking into account of current temperature, pandemic situation and other factors within minutes, and they will automatically inform the workers whether to come for the shifts today or not. This last-minute scheduling instruction by the scheduling software injects turbulence in the workers' schedules.

Such unpredictability in the work schedule can have adverse ramifications for the workers. Workers can find it difficult to plan for family matters (e.g., childcare arrangements), or predict the exact income as these workers are paid on an hourly basis (Miller 2019). This is made worse by the fact that many of such workers belong to the lower income group and are financially stretched. In addition, there are also research showing that such unpredictable work schedule may cause even more psychological distress than low wages (Schneider and Harknett 2019). Such findings mean that the unpredictable work schedules warrant equal attention as compared to the on-going rallying cry for an increase in the minimum wage. Therefore, workers, especially those in the retail, food, and hospitality industries, have begun asking for predictable schedules to balance their work and personal lives better. In response to these difficulties, many cities, in recent years (from 2017 to 2022), are considering a new type of law known as predictive scheduling law, which requires an employer to notify an employee of their work schedule in advance.

The predictive scheduling laws aim to address businesses operating in industries that frequently employ on-call scheduling practices, where the employees receive the minimum wage and are paid hourly. These laws primarily target the retail and restaurant sectors, which often experience significant fluctuations in their operational demands. While the law enacted in each of the cities or state may differ in its details, they all have the following common aspects:

- Employers must provide employees with advance notice of their schedules. For example, Oregon, San Francisco, and Philadelphia have all stated that the employers must give 14 days of advance notice to the employees if they wish to adjust their schedules without any penalty.
- Employers must provide a compensation premium to the employee if they change his schedule without advance notice. For example, Oregon, Philadelphia and Seattle, requires an extra one hour of pay for added shift and one-half times of regular rate of pay for cancelled shift, while New York City requires $15 for added shift and $75 for cancelled shift.
- Employers must allow the employee to have the right to provide input into his schedule. Although the employers are under no obligation to grant the employee's request, they may not retaliate against the employee for making the request.

However, smaller firms are exempted from the predictive scheduling laws. For example, Oregon and Seattle state that only employers that have at least 500 employees worldwide are required to adhere to the law. The law makers believe that most small firms do not have access to large human resources and often already have a hard time attracting workers. There is also high unpredictability of the staffing needs for smaller companies due to larger fluctuations in demands. As a result of the implementation of the predictive scheduling law, there are a few firms that have been fined due to violation of the law[1].

Nevertheless, the question remains open on whether this law is beneficial or not in practice. While these laws are designed to provide workers with a "good faith" estimate of their upcoming schedule, there is a potential loss of income for workers as employers were unable to offer extra shifts at a moment's notice, which meant fewer available shifts for workers. Employers may also have a hard time accommodating fluctuating labor needs and had to adjust their employee's composition. Organizations like the New York State Restaurant Association and the Restaurant Law Center had also challenged this law in state court. They believed that targeting only the bigger firms meant that only a small subset of the industry is purposely targeted and is unfair and discriminating. They also argued that such a law will have a negative impact on the industry as employers would not be able to improve their operating results and promote pro-growth policies, which may be detrimental to the entire market, including the labor market. Moreover, most of these laws are drafted together with the worker unions and have little input from the firms and thus, may not capture

[1]Chipotle and Macdonald in New York City, and Target in Philadelphia had been sued in 2021 for violating the predictive scheduling law by not posting the weekly work schedules two weeks in advance and not paying any compensation premium to the workers (Scheiber 2021, NYC 2021 and Reyes 2021).

the concerns of the firms. In fact, there are states that specifically banned the implementation of any predictive scheduling law, such as Georgia and Arkansas. Thus, there is no common consensus on the predictive scheduling law.

Hence, we attempt to study the impact of the predictive scheduling law on a firm's hiring and scheduling practices. We want to answer the following questions. How should firms adjust their workforce and contract hours with the implementation of the predictive scheduling law? What is the impact of the predictive scheduling law on the worker's earnings? Does the predictive scheduling law have an impact on a higher labor market density?

We first analyze the law using a game theoretical model to derive some hypotheses regarding the predictive scheduling law. Next, we verify our hypotheses empirically and numerically. We find that if the predictive scheduling law is implemented, the firm tends to hire more workers if the compensation premium for adding shifts at the last minute is high, and tends to hire fewer workers if the compensation premium for canceling shifts at the last minute is high. Moreover, if both compensation premiums are equal, the firm will only hire more workers and boost the overall employment level only if the labor market thickness is low. Thus, while the predictive scheduling law can still potentially protect the overall employment level, it is ineffective in forcing the firms in region of higher market thickness to boost their employment.

Moreover, the workers' earnings are affected differently depending on how much the law penalizes the firm for adding vs canceling shifts, and are in the opposite direction as the employment level trend. Having a high compensation premium for adding extra shifts may tend to increase the the number of workers hired but decreases each individual worker's social welfare. The opposite is true for the compensation premium for canceling shifts. This implies that the policy maker has to be cautious about the magnitude of the two different compensation premiums, and has to choose the appropriate level of cost premium for the firm, depending on whether the policy maker wants to boost the welfare of the hired workers or the overall population.

## 2.2 Literature Review

Our paper is related to the following streams of literature: (1) workers staffing and scheduling, (2) capacity flexibility, and (3) labor laws. As labor expense is one of the largest cost component in many industries, the operations management has been particularly focused on workers staffing and scheduling in the past few decades. Ernst et al. (2004) and Van den Bergh et al. (2013) provide an extensive list of papers that have studied on analytical staffing model. Recently, there has been a trend to embark on empirical studies on the staffing level in food and service industries. For example, there are studies on the impact of staffing levels on a retailer's sales based on a range of performance metrics, such as conversion rate, basket value, sales, and profitability (e.g., Fisher et al. 2006, Netessine et al. 2010, Perdikaki et al. 2012, Mani et al. 2015, Chuang et al. 2016, Musalem et al. 2021 and Fisher et al. 2021). Our study differs from the above in its research question, data, and methodology. We investigate the level of staffing in Oregon state using the nation-wide data that covers the payroll information of the entire food industry before and after the implementation of the predictive scheduling law. This allows us to study the impact of the law on the entire industry, and not just limited to a specific firm.

More recently, there are a few papers that focus on the scheduling practices of retailers and restaurants. Previous analytical studies in these areas, especially in just-in-time (JIT) scheduling, have not considered the workers' well-being in their analysis. For example, Kamalahmadi et al. (2021) study how JIT scheduling affect productivity by analyzing the 2016 data of 25 stores in the Northwestern part of US from January 2016 to September 2016. They find that workers are less likely to up-sell to the customers if they have to work past their scheduled hours without being informed in advance. In addition, by assuming that the workers only experience productivity drop if they are schedule more shifts in real-time, they found that providing predictable work schedules may improve the restaurants' expected profit by up to 1%. Our study differs from theirs in two ways. Firstly, their study do not consider the effect of the predictive scheduling law. Although one of the restaurants covered in their study is in Seattle, where a predictive scheduling law is being implemented in 2017, their data periods do not covered 2017 and thus, they do not consider the city wide impact of the law on a particular restaurant chain. Secondly, in their study of the benefit of a more predictive work schedules, they have assumed an unequal drop in the worker's productivity when the shifts are canceled or when the shifts are added, and an unequal cost compensation from canceling a shift or adding a shift. Thus, the result of an improvement in the profit by adopting a predictive work schedule is mainly driven by the asymmetric cost associated with schedule changes. Nevertheless, if the predictive scheduling law is implemented, there may not be any decrease in workers' productivity since the workers are compensated for the schedule changes and have greater utilities. Hence, in the presence of predictive scheduling law, the benefits of JIT scheduling is still uncertain. In our study, we do not make an assumption on the worker's productivity, and the predictive scheduling law targets the JIT scheduling specifically by rendering such scheduling practices to be more costly. This allows us to claim with greater confidence on whether the JIT scheduling is worse off under the current practices and regulations.

Another related work is by Kesavan et al. (2022). Using a field experiment conducted in 28 stores in the San Francisco and Chicago metropolitan areas from November 2015 to August 2016, they explore the impact of different interventions in terms of schedule consistency, predictability, adequacy, and control, and find that improvement in these properties is able to improve the store productivity. Thus, their study imply that the store needs not increase the staffing level even when labor flexibility is reduced. Similar to the study by Kamalahmadi et al. (2021), their study focus on investigating how the productivity changes with scheduling practices, which indirectly affect the store profit. In our paper, we have abstracted away from the productivity changes and instead focus squarely on the direct impact of greater scheduling predictability and negotiating power of the workers on the staffing level. Moreover, while some of the dimensions of work schedules targeted by Kesavan et al. (2022) also align with the predictive scheduling, their study limit the impact of responsible scheduling within the store and do not consider the overall impact when such scheduling practices is being implemented city or state wide.

There is also a wide stream of literature on the regulations of labor standards and practices. More specifically, much of these literatures focus on the minimum wage regulation since the Fair Labor Standards Act (FLSA) is introduced in 1938. There are several theory models (e.g., Aaronson and French 2007) on the impact of the minimum wage increase on employment and total earnings of employed workers. These models show the employment effect varies as a function of labor and product market competition, factor substitutability, and other factors. There is also a large stream of empirical work in this area with conflicting findings on the impact of regulations on the workers' employment and earnings, with some finding a positive impact on employment and earnings (e.g., Card and Krueger 2000 and Dube et al. 2010) and others finding a contrary result (e.g., Neumark and Wascher 2000 and Aaronson et al. 2008). More recently, under the operations management literature, Yu et al. (2022) find that an increase in the minimum wage can increase the workers' schedule variability. Nevertheless, the FLSA also introduced another important wage regulation, which is that an overtime wage of at least one and one-half of the hourly wage have to be given if a worker worked in excess of 40 hours. While the overtime law garners less attention as compared to the minimum wage, there are studies that focus on the impact on the workers' welfare (e.g., Trejo 1991 and Trejo 1993) and studies that focus on the firm's service quality as a result of the law (e.g., Lu and Lu 2017). In essence, our study builds on the current literature on regulation as we focus our attention on the predictive scheduling law, which is applied to workers that are eligible to be protected by the minimum wage law and the overtime law. Nevertheless, the predictive scheduling law differs from the two laws (i.e., minimum wage law and overtime law) as it accounts for the variability in the usual hours worked by the workers even if the employer may not run foul of the previous two laws. For example, the firm can schedule a worker for less than 40 hours a week and pay him the minimum wage and yet it adds or removes shifts at a last minute notice. In this case, the predictive scheduling law will apply. On this front, as the predictive scheduling law is still relatively nascent, there are only some preliminary studies that attempt to find out on the effect of such law on the workers' welfare (e.g., Harknett et al. 2021 and Dunn et al. 2022). Thus, our paper is one of the first to study the impact of predictive scheduling law on firm's staffing level.

## 2.3 Model

To gain deeper insights into the overall impact of the predictive scheduling law on the economy, we begin by analyzing a game-theoretic model. This approach allows us to generate hypotheses regarding the potential effects of the law.

### 2.3.1 Sequence of Events

We assume that there are $N$ number of firms and $M$ number of workers over an infinite horizon period. At the beginning (i.e., period 0), all the firms face a hiring game, where each firm compete with one another to hire the workers to work for them. This is to simulate the frictional labor market as it can be difficult to hire the workers depending on the labor market thickness. For simplicity, the workers do not leave once they are hired. Thus, the workers are contracted for by a firm $i$ for a long term basis, and they constitute the available workforce or manpower that a firm can utilize in each period. Each firm $i$ hires $L_i$ number of workers, who are meant to work for each period. Thus, each worker is suppose to work one shift in each period. We assumed that demand $\lambda$ is constant in each period and the firm has to ensure that the total manpower hired is sufficient to meet the demand (i.e., $L_i \geq \lambda$). Thus, the firm adopts a "hire-up-to" policy. Each period is then split into two sub-periods: (1) a certain proportion of workers will be absent for each firm, and (2) the firm has to adjust the number of workers and their shifts for that period in order to meet the demand.

In each period $t$, only $\gamma_{it}$ proportion of the workers will show up for their shifts for firm $i$. $\gamma_{it}$ is a random variable that affects the number of workers that turn up for that period. Alternatively, it can also reflect the turn-out rate for that period. For example, if $\gamma_{it} = 0.7$, it means that each worker works only on average 70% of his total scheduled shifts for that period, due to his own absenteeism. Thus, there will be $1 - \gamma_{it}$ proportion of absentees at each firm at each period, which is revealed at the start of the period. For simplicity, we assume that $\gamma_{it}$ follows a uniform distribution and is independently distributed across time. Subsequently, under the first sub-period, the firm can then decides on the number of workers to adjust, $x_{it}$, in order to fulfill the demand at the second sub-period. Figure 2.1 shows the sequence of events for a particular firm.

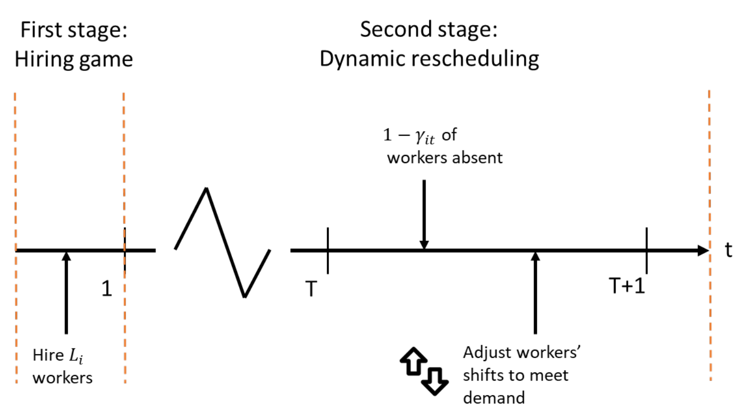



Figure 2.1: Sequence of events

### 2.3.2 Preferences and Utilities

As described earlier, some workers may not be fully available for a particular period and a firm's available workforce (i.e., the number of manpower) changes with time. Thus, the total profit generated over time is given by the sum of the revenue generated and the labor cost incurred for each period. The revenue generated at a particular period is the minimum of the demand realization $\lambda$ and the amount of manpower available. We assume that one unit of demand can be fulfilled by one unit of man-hour. Such setting is typical of a standard newsvendor model where a firm has to allocate the right amount of resources to meet the demand. To focus on the workers' uncertain availability rather than the demand fluctuation, which may be predicted with greater certainty using current technology based on seasonality or other factors, we let the demand per period be deterministic. Hence, the expected total profit earns by a firm over time is

$$\Pi_{it} = \mathbb{E}\Big[\sum_{t=1}^{\infty} \delta^t [p \min[\lambda, \gamma_{it} L_i + x_{it}] - w\gamma_{it} L_i - x_{it}(w + c_1)\mathbf{1}_{x_{it} \geq 0} + x_{it}(w - c_2)\mathbf{1}_{x_{it} < 0}],$$

where $\delta$ is the discount rate, $p$ is the revenue per unit demand, $w$ is the hourly wage of a worker, $c_1$ is the compensation premium per shift to be provided if the worker has to work more than the original shift and $c_2$ is the compensation premium per shift to be provided if the worker is asked not to come for that shift. Note that $c_1$ and $c_2$ are both less than $w$.[2] For example, the predictive scheduling law in Oregon states that the employer must pay an extra one hour of pay for added shift and one-half times of regular rate of pay for canceled

[2]In practice, the mandated compensation premium does not exceed the hourly wage. Moreover, it is also trivial to analyze the case where $c_1$ and $c_2$ are both larger than $w$ as in this case, the firm does not adjust the work schedule in the last minute at all since the labor cost is higher.

shift. In this case, the compensation premium for adding shift $c_1$ corresponds to $w$ and the compensation premium for reducing shift $c_2$ corresponds to $0.5w$.

For the initial hiring of the workers at Period 0, note that the cost of hiring is affected by the probability of the vacancy being filled and the competition with other firms. In other words, the firm incurs a cost of $c_v$ per vacancy being posted and advertised. The probability of a vacancy being filled at firm $i$ is given by $\frac{M}{\sum L} = \frac{M}{L_i + \bar{L}}$, where $\bar{L} = \sum_{N-1} L$. Thus, the cost of hiring a worker is inversely proportional to the probability of successfully filling up a vacancy and is given by

$$c_v \frac{1}{\frac{M}{\sum L}} L_i = c_v \frac{L_i + \bar{L}}{M} L_i.$$

Such cost of hiring accounts for the market friction (Hawkins 2015 and Kudoh et al. 2019). Thus, a firm's expected utility is represented by

$$\begin{aligned} \Pi_i &= - c_v \frac{L_i + \bar{L}}{M} L_i + \Pi_{it} \\ &= - c_v \frac{L_i + \bar{L}}{M} L_i + \sum_{t=1}^{\infty} \delta^t \, \mathbb{E}[p \min[\lambda, \gamma_{it} L_i + x_{it}] - w\gamma_{it} L_i - x_{it}(w + c_1)\mathbf{1}_{x_{it} \geq 0} \\ &\quad + x_{it}(w - c_2)\mathbf{1}_{x_{it} < 0}]. \end{aligned} \tag{2.1}$$

For the workers, we assume that they are just earning the wages based on the number of hours that they worked and the appropriate compensation premium if any. There is no effort cost. Thus, a hired worker's per period utility at firm $i$ is given by

$$u_{it} = \begin{cases} w & \text{if he is not absent,} \\ w + c_1 & \text{if he is not absent and he has to work more shift,} \\ c_2 & \text{if he is not absent and his shift is cancelled,} \\ 0 & \text{if he is absent.} \end{cases} \tag{2.2}$$

Consequently, the worker's expected total utility is $u_i = \sum \delta^t \, \mathbb{E}[u_{it}]$.

## 2.4 Equilibrium Analysis

In this section, we provide the results of the equilibrium analysis. The game is solved via backwards induction, starting from the step where the firm has to make adjustment to its work schedule to the first step where it has to make the hiring decision on the number of workers to hired. The proofs for all the propositions can be found in Appendix B.1. We begin with the most crucial results regarding the staffing strategy for a firm.

**Proposition 2.1** *The optimal staffing level for a firm $L_i^*$ is given by the unique solution of $\lambda^2 M(c_1 + p - w) + 2c_2 M\left(\lambda^2 - (L_i^*)^2\right) + 4c_v(\delta - 1)(L_i^*)^3(N+1) = 0$, which is increasing in $c_1$ and decreasing in $c_2$. Moreover, if $c_1 = c_2 = c$, there exists a threshold $\bar{M}$, where $\bar{M}$ is a solution of $3\lambda^2 = 2(L_i^*)^2$, such that $L_i^*$ is increasing in $c$ if and only if $M \leq \bar{M}$.*

Proposition 2.1 demonstrates that the compensation premium for additional shifts or canceled shifts has contrasting effects on the firm's hiring decision. An increase in the compensation premium for extra shifts ($c_1$) leads to the firm hiring more workers, while an increase in the compensation premium for canceled shifts ($c_2$) results in the firm hiring fewer workers. This finding aligns with intuitive reasoning. When the cost of adjusting shifts upward rises, the firm can opt for a higher initial number of regular schedule workers and subsequently reduce their shifts at the last minute based on actual labor requirements and demand, as the cost of cancellation is relatively lower. Conversely, if the cost of cancellation is higher, the firm aims to avoid potential labor cost increases associated with the need to cancel shifts, leading to a reduction in the number of workers hired. Therefore, the effects of the two compensation premiums act in opposing directions. These findings also suggest that the implementation of predictive scheduling laws can contribute to stabilizing schedule variability, as it renders just-in-time (JIT) scheduling more costly.

Proposition 2.1 also reveals that the firm employs more manpower when the compensation premium for adding shifts is higher, and conversely, utilizes less manpower when the compensation premium for canceling shifts is lower. This result may initially appear counter-intuitive, as one would expect that a higher cost for adding shifts would lead to fewer shifts being added, resulting in a lower total scheduled manpower. However, our analysis demonstrates the opposite outcome. We find that when the cost of adding shifts is higher, the firm chooses to hire more workers at the initial stage (as indicated in Proposition 2.1), thereby reducing the need to add shifts later on. Consequently, the firm is more likely to have sufficient manpower to handle realized absenteeism and demand in subsequent periods. This reduces the incidence of having inadequate manpower at the later periods, even when the number of absentees is high. Thus, the manpower are utilized more and the total manpower scheduled is higher. On the other hand, if the cost of canceling shifts is higher, the firm hires fewer workers to minimize the necessity of canceling shifts later. The firm is more willing to tolerate an inability to meet customer demand, even in the presence of high worker absenteeism. Consequently, fewer manpower resources are utilized and scheduled by the firm.

Furthermore, Proposition 2.1 states that if the same compensation premium applies for both the adding and canceling of shifts (i.e., $c_1 = c_2 = c$), the firm will only hire more workers if the labor market thickness is sufficiently small (i.e., $M \leq \bar{M}$). Such adoption of similar compensation premium for both the adding and canceling of shifts may be quite common in future as it is straightforward and less prone to mistakes when the manager or the employer calculates the total wages a worker is entitled to. In fact, we found that there are places that adopt such a policy at present (e.g., San Francisco city and Oregon state). When the labor market thickness is small, there may not be enough workers for the firms to play the game of hiring more workers and dropping them off at the last minute. Thus, the firms would rather hire more workers first as they would rather want to have sufficient workers to meet the demand than trying to cut cost using just-in-time scheduling. In this case, the result suggests that for the same compensation premium, the impact of adding extra shifts outweighs the impact of canceling shifts as the firms are accounting for the fact that they may have to add more shifts later, since the labor market thickness is not large enough.

**Proposition 2.2** *Suppose $w \leq 2c_2 + c_1$. The expected wages for a worker per period is decreasing in $c_1$ and increasing in $c_2$. Moreover, if $c_1 = c_2 = c$, the expected wages is decreasing in $c$ if and only if $M \leq \bar{M}$.*

Moreover, for each individual worker, we find that if the original hourly wage is small (i.e., $w \leq 2c_2 + c_1$), the worker's earning is decreasing if the compensation premium for adding a shift increases and is increasing if the compensation premium for canceling a shift increases. The trend of a worker's earning is also found to be in opposite direction as the overall employment level as stated in Proposition 2.1. Thus, if the intention of the law is to help a worker to secure more earnings, the policy maker should pay attention to the magnitude of both compensation premium ($c_1$ and $c_2$). The compensation premium of adding extra shifts may tend to help the overall worker population while the compensation premium of canceling shifts may tend to help only individual workers that are hired in the industry.

Therefore, based on our theoretical results, we have the following hypotheses for our empirical analyses that follow. As we are concerned on how a firm's staffing strategy and a worker's earning will change after the law, we are first going to verify that the trend of the employment level and the workers' earnings are in the opposite direction after the enactment of the predictive scheduling law (Hypotheses 2.1a and 2.1b). Moreover, as the law may have a differential impact depending on the prevailing market conditions, we also seek to verify Hypothesis 2.2.

**Hypothesis 2.1a** *Oregon's employment increases and the worker's earnings decreases after enactment of the predictive scheduling law.*

**Hypothesis 2.1b** *Oregon's employment decreases and the worker's earnings increases after enactment of the predictive scheduling law.*

**Hypothesis 2.2** *The impact on employment is more negative for thicker market and the impact on earning is more positive for thicker market.*

## 2.5 Data and Identification Strategy

Having derived hypotheses from our analytical model, we now embark on the empirical validation of these hypotheses using real-world data. This approach enables us to test the accuracy and applicability of our theoretical predictions in a practical context.

### 2.5.1 Data Sources

Our main analyses rely on the Quarterly Census of Employment and Wages (QCEW), which is obtained from the Bureau of Labor Statistics. The QCEW provides a quarterly count of the employment and wages reported by employers, based on the ES-202 filings that every establishment is required to submit quarterly for the purpose of calculating payroll taxes related to unemployment insurance. Since 98% of workers are covered by unemployment insurance, the QCEW constitutes a near-census of employment and earnings. Thus, the QCEW is able provide us with the county-level data by the detailed industry, which allow us to study the impact of the predictive law on the specific industries affected by the law.

We focus on our study on the Oregon state, where there is a state-wide implementation of the predictive scheduling law in 2017. The law requires employers in the retail, hospitality and food services industries to adopt predictive scheduling, such as posting and providing workers' schedules in writing at least 14 calendar days in advance. As food industry has the highest proportion of minimum wage workers, which is the target of the predictive scheduling law, we further refine our focus on the food industry. To cover the implementation period of the predictive scheduling law in July 2017, we use the data from 2015 to 2019.

Notice that the period covered is for a short duration of about 5 years. This is because the period after the implementation of the predictive scheduling law coincided with a severe disruption to the service industry due to the COVID-19 pandemic. The pandemic disproportionately affected the food and service industry as the strict lockdown ordered by the government in 2020 resulted in many restaurants and entertainment centres being unable to receive customers. Thus, many service workers were out of jobs in the early pandemic days due to lack of demand. Moreover, the subsequent complications of the fear of facing difficult and possibly COVID-19 infectious customers and the prospect of receiving the high unemployment benefits resulted in staffing shortage in the service industry, even after lockdown requirements are lifted (Littman 2021). All these resulted in huge disruption to the labor demand. Thus, to avoid the COVID-19 pandemic period in the United States, which occurs at the beginning of 2020, we restrict our data to January 2015 to December 2019 for the rest of the analysis, where we cover 2 years before and after the law is being enacted in 2017.

### 2.5.2 Empirical Strategy

Our study focuses on three key outcome measures to assess the impact of the predictive scheduling law: total employment, average earnings per worker, and total wages of the workers. These measures effectively capture the comprehensive labor conditions following the implementation of the law, enabling us to validate our hypotheses. By examining the total employment figure, we can gauge the overall workforce size and ascertain whether any significant changes have occurred as a result of the predictive scheduling law. This measure provides valuable insights into the potential impact on job availability and stability. The average earnings per worker is another crucial metric we analyze. It enables us to understand how the law affects individual workers' income levels, indicating whether the law has led to any notable improvements or disparities in wages. Additionally, we consider the total wages of the workers as an outcome measure. This measure accounts for both employment levels and earnings, offering a comprehensive view of the collective financial impact on the workforce. By assessing the total wages, we gain insights into the overall economic implications of the predictive scheduling law. Together, these outcome measures play a vital role in describing the labor conditions comprehensively following the implementation of the predictive scheduling law. Moreover, they serve as empirical evidence to validate our hypotheses and shed light on the true effects of the law on the workforce.

Our first identification strategy is to use the difference-in-difference (DiD) approach. The difference-in-difference method is a statistical technique used to estimate the causal effect of a treatment or intervention by comparing the changes in outcomes over time between a treatment group and a control group. It aims to capture the difference between the pre-treatment and post-treatment periods for both groups and then compare the difference in those differences. To use this approach, we estimate the following specification:

$$Y_{it} = \alpha X_{it} + \beta_1 Oregon_i + \beta_2 Enacted_t + \beta_3 Oregon_i \times Enacted_t + \theta_s + \tau_t + \epsilon_{it}, \quad (2.3)$$

where $Y_{it}$ represents an employment condition of county $i$ in quarter/year $t$. For example, $Y_{it}$ can represent $\ln(Wage_{it})$, which is the logarithmic value of the average earning of a worker in a quarter in county $i$ in quarter/year $t$. The variable $Oregon_i$ distinguishes observations in the "treatment" group (individuals that lived in the Oregon state) from those in the "control" group (individuals that lived outside the Oregon state), and the variable $Enacted_t$ indicates observations in the post enactment of the predictive scheduling law. $\theta_s$ is the county fixed effect and $\tau_t$ is the time fixed effect. The county fixed effects capture any time-invariant factors that affected the average employment outcome within each county while the time fixed effects capture any time factors that were common across states, such as the business cycle. The vector $X_{it}$ represents the county characteristics, which include the minimum wage, total employment level, population, and the number of establishments. $\beta_3$, which is the coefficient of interest, highlights the interaction between $Oregon_i$ and $Enacted_t$ as it identifies the changes in the employment outcome in the Oregon state relative to that in the control group after the law is enacted.

We begin our analysis by comparing Oregon with Washington. Washington is north of Oregon, and has a similar geography and climate to Oregon. Both states are also sparsely populated and have a similar political inclination (Jones 2023b). State similarity indexes developed for the purpose of forecasting elections based on the k-nearest neighbors approach on the demographic information, have all found Washington to be the most similar state (Silver 2008, Jarman 2020). Moreover, by accounting for equal weights of the five major aspects of states: demographics, culture, politics, infrastructure, and geography, it is found that Washington is the most similar state to Oregon (Jones 2023a). This is also validated by a large language model, ChatGPT (Jones 2023a). Hence, Washington is selected as the most suitable control state.

## 2.6 Empirical Results

### 2.6.1 Main Analysis

All models are estimated via generalized least squares (GLS), weighted by the county population. Results presented contain robust standard errors, corrected for clustering on the state. The discussion of the results focuses exclusively on the effect of predictive scheduling law.

*Employment and Wage Effect*: We first examine the impact of predictive scheduling law on the employment level. The employment level provides a direct evidence on the overall staffing level. To this end, we estimate the following regression based on Equation (2.3):

$$\begin{aligned}\log(Employment_{it}) =& \alpha X_{it} + \beta_1 Oregon_i + \beta_2 Enacted_t + \beta_3 Oregon_i \times Enacted_t \\ &+ \theta_s + \tau_t + \epsilon_{it}, \end{aligned} \tag{2.4}$$

where $Employment_{it}$ is the quarterly employment level for a specific industry at county $i$ during time $t$. We next examine the impact of the predictive scheduling law on the earnings of an individual worker as follows:

$$\begin{aligned}\log(Earnings_{it}) =& \alpha X_{it} + \beta_1 Oregon_i + \beta_2 Enacted_t + \beta_3 Oregon_i \times Enacted_t \\ &+ \theta_s + \tau_t + \epsilon_{it}, \end{aligned} \tag{2.5}$$

where $Earnings_{it}$ is the average quarterly earnings of a worker in a specific industry at county $i$ during time $t$. Thus, from Equations (2.4) and (2.5), we obtain the first two columns of Table 2.1, which shows the impact of the predictive scheduling law on the food industry affected by the law.

Based on the findings presented in the first two columns of Table 2.1, we can observe a decrease in employment levels and an increase in individual wages following the implementation of the predictive scheduling law. This observation provides support for Hypothesis 2.1b, further strengthening our confidence in the ability of our theoretical model to explain the impact of the predictive scheduling law.

*Total Wage Effect*: Finally, we examine the impact of the predictive scheduling law on the total earnings of all workers. To this end, we estimate the following

Table 2.1: The effects of predictive scheduling law on employment and worker's earning in the food industry based on QCEW data from 2015 to 2019

| Variables | (1)<br>Log(Employment)<br>b/(se) | (2)<br>Log(Wage)<br>b/(se) | (3)<br>Log(Total Wage)<br>b/(se) |
|---|---|---|---|
| Enacted | 0.004 | -0.013 | -0.009 |
| | (0.007) | (0.004) | (0.011) |
| Treated State | -0.062 | -0.066 | -0.127 |
| | (1.410) | (0.342) | (1.068) |
| Enacted × Treated State | -0.010* | 0.012* | 0.002* |
| | (0.001) | (0.001) | (0.000) |
| Log Minimum Wage | 0.041 | 0.147** | 0.187** |
| | (0.010) | (0.006) | (0.004) |
| Log Total Employment | 0.383 | 0.203 | 0.587 |
| | (0.103) | (0.055) | (0.157) |
| Log Establishment | 0.460** | -0.110** | 0.350** |
| | (0.010) | (0.002) | (0.012) |
| Log Population | 0.093 | -0.149 | -0.056 |
| | (0.389) | (0.188) | (0.201) |
| Constant | 0.202 | 8.077 | 8.279 |
| | (6.027) | (1.684) | (4.343) |
| $n$ | 1404 | 1404 | 1404 |
| $R^2$ | 1.00 | 0.98 | 1.00 |

Notes: The table contains estimated coefficients associated with the variable listed in the leftmost column and the standard errors are in parentheses. Only the relevant effects are shown. All regressions contain county fixed effects, quarter fixed effects and year fixed effects.
$^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

regression based on Equation (2.3):

$$\log(TotalEarnings_{it}) = \alpha X_{it} + \beta_1 Oregon_i + \beta_2 Enacted_t + \beta_3 Oregon_i \times Enacted_t + \theta_s + \tau_t + \epsilon_{it}, \quad (2.6)$$

where $TotalEarnings_{it}$ is the total quarterly earnings of all worker in a specific industry at county $i$ during time $t$. Thus, from Equation (2.6), we obtain Table 2.1, which shows the impact of the predictive scheduling law on the total wages paid out in the food industrt.

Based on the data presented in Table 2.1, it is evident that total wages have decreased in the food industry subsequent to the implementation of the predictive scheduling law. This observation suggests that while the law may enhance the earnings of individual workers, which can be a compelling selling point for policymakers, it may have a detrimental effect on overall labor welfare. Consequently, it becomes imperative to conduct further in-depth analysis and engage in comprehensive discussions regarding the predictive scheduling law before considering its widespread implementation. Such examinations should take into account the broader implications and potential trade-offs associated with the law to ensure a holistic understanding of its effects on the labor market.

### 2.6.2 Heterogeneous Effect

As we hypothesize that the predictive scheduling law can have a heterogeneous impact based on labor market thickness, our attention now turns to examining the law's effects on different labor markets. To assess this, we adopt two different measures to categorize the counties separately into a low or high market density market. We introduce a dummy variable, denoted as *LargeDensity*, which classifies counties based on their number of workers per establishment. Counties with an average of more than 15 workers per establishment as counties with high market thickness. Hence, *LargeDensity* takes a value of 1 if the county's workers per establishment is 15 or higher, and 0 otherwise. Thus, we obtain Table 2.2 based on this measure. Next, we alternatively use the dummy variable *LargeDensity* to classify counties based on their population density. Counties with more than 100 people per square mile are categorized as high-density areas, indicating a thicker labor market. Hence, *LargeDensity* takes a value of 1 if the county's population density is 100 per square mile or higher, and 0 otherwise. Thus, we obtain Table 2.3 based on this measure. We employ the difference-in-difference-in-differences (DDD) approach to study the heterogeneous impact of the predictive scheduling law.

Table 2.2: Estimating the heterogeneous effect of predictive scheduling law based on workers per establishment.

| Variables | (1) Log(Employment) b/(se) | (2) Log(Wage) b/(se) |
|---|---|---|
| Enacted | 0.006 | -0.006 |
| | (0.009) | (0.004) |
| Treated State | -0.097 | 0.059 |
| | (1.356) | (0.368) |
| Enacted × Treated State | 0.001 | -0.006 |
| | (0.001) | (0.002) |
| Large Density | 0.308 | 0.069* |
| | (0.071) | (0.011) |
| Enacted × Large Density | -0.004 | -0.012** |
| | (0.003) | (0.001) |
| Enacted × Treated State × Large Density | -0.023* | 0.034** |
| | (0.003) | (0.001) |
| Log minimum wage | 0.041 | 0.147** |
| | (0.009) | (0.006) |
| Log Total Employment | 0.388 | 0.220 |
| | (0.102) | (0.051) |
| Log Establishment | 0.460** | -0.111*** |
| | (0.012) | (0.001) |
| Log Population | 0.077 | -0.125 |
| | (0.368) | (0.191) |
| Constant | 0.350 | 7.590 |
| | (5.774) | (1.779) |
| $n$ | 1404 | 1404 |
| $R^2$ | 1.00 | 0.98 |

Notes: The table contains estimated coefficients associated with the variable listed in the leftmost column and the standard errors are in parentheses. Only the relevant effects are shown. All regressions contain county fixed effects, quarter fixed effects and year fixed effects. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

From Table 2.2 , our coefficient of interest on $Enacted \times TreatedState \times LargeDensity$ , which is the DDD estimator. We can observe that the coefficient DDD estimator is negative for the employment but positive for the individual

Table 2.3: Estimating the heterogeneous effect of predictive scheduling law based on population level.

| Variables | (1)<br>Log(Employment)<br>b/(se) | (2)<br>Log(Wage)<br>b/(se) |
|---|---|---|
| Enacted | 0.008 | 0.001 |
| | (0.011) | (0.002) |
| Treated State | -0.177 | 0.399 |
| | (1.284) | (0.458) |
| Enacted × Treated State | -0.005 | -0.013** |
| | (0.005) | (0.000) |
| Large Density | 0.304 | 0.087* |
| | (0.068) | (0.013) |
| Enacted × Large Density | -0.005 | -0.017** |
| | (0.005) | (0.001) |
| Enacted × Treated State × Large Density | -0.011 | 0.037** |
| | (0.008) | (0.002) |
| Log Minimum Wage | 0.043 | 0.142** |
| | (0.007) | (0.005) |
| Log Total Employment | 0.386 | 0.214 |
| | (0.104) | (0.050) |
| Log Establishment | 0.465** | -0.117* |
| | (0.018) | (0.016) |
| Log Population | 0.045 | 0.010 |
| | (0.333) | (0.210) |
| Constant | 0.737 | 6.033 |
| | (5.410) | (2.110) |
| $n$ | 1404 | 1404 |
| $R^2$ | 1.00 | 0.98 |

Notes: The table contains estimated coefficients associated with the variable listed in the leftmost column and the standard errors are in parentheses. Only the relevant effects are shown. All regressions contain county fixed effects, the quarter fixed effects and year fixed effects. $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

wage. Similarly, from Table 2.3, we can observe that the coefficient of the DiD estimator is more significant and negative for the employment level in a thicker market and is more significant and negative for the individual wage in a thicker market. These findings support our Hypothesis 2.2, which suggests that the impact on employment is more negative in thicker labor markets, while the impact on earnings is more positive in thicker labor markets.

## 2.7 Discussion

In conclusion, it is evident that the implementation of a predictive scheduling law has the potential to significantly impact both employment and wages. Such legislation introduces new requirements and regulations on employers, altering the dynamics of workforce scheduling and management. While the intended aim of these laws is to provide stability and protect the rights of workers, their consequences may have broader implications, especially on the employment level and workers' earnings as discussed in the earlier sections of this paper.

Our analysis reveals that the compensation premiums for adding shifts and canceling shifts have contrasting effects on the firm's hiring decisions. Specifically, when the compensation premium for adding shifts increases, the firm tends to hire more workers. On the other hand, when the compensation premium for canceling shifts increases, the firm hires fewer workers. As a result, worker earnings exhibit an inverse relationship with employment levels. With a larger workforce, individual workers are utilized less and consequently earn lower wages. Furthermore, our study explores the scenario where the policymaker establishes equal compensation premiums for adding and canceling shifts, as seen in the case of Oregon state. We observe that in such instances, the employment level increases with the compensation premium, while individual worker earnings decrease, but only when the labor market thickness is small.

While the current paper has focused on a limited study period due to data constraints, it is important to acknowledge that there may be various factors that influence employment levels and workers' earnings in the long run when a state implements predictive scheduling laws. Businesses may respond to the implementation of predictive scheduling laws by exploring alternative staffing models, including increased automation, such as the use of self-checkout kiosks in fast-food restaurants. These changes in staffing practices have the potential to affect overall employment levels and alter the nature of job opportunities available in the industry.

To better understand the consequences of predictive scheduling laws, future studies should focus on several areas. Comprehensive empirical research is needed to assess the actual effects on employment levels, both in terms of overall job opportunities and specific industries or sectors. This would provide a clearer picture of the trade-offs between worker protections and potential reductions in employment. Another possible future work includes examining the long-term effects on wages and compensation structures. By analyzing the impact of predictive scheduling laws on wage growth, income inequality, and the stability of workers' earnings, researchers can assess the overall effectiveness of these policies in improving workers' financial well-being. Lastly, future studies could also explore the potential effects of predictive scheduling laws on business viability, industry competitiveness, and regional economic dynamics. Such research can inform policymakers and stakeholders about the balance between worker protections and the economic considerations that affect the sustainability and growth of businesses.

By undertaking comprehensive studies in these areas, policymakers and stakeholders can make informed decisions about the design and implementation of predictive scheduling laws, striking a balance between safeguarding workers' rights and ensuring a thriving and resilient economy.

CHAPTER 3

# FREELANCERS OR EMPLOYEES? A FIELD EXPERIMENT WITH A FOOD DELIVERY PLATFORM

## 3.1 Introduction

The food delivery industry has changed significantly over the years. Traditionally, restaurants hire employees directly for food delivery services, providing them with regular wages and benefits. The restaurants will then have control over their work schedules and operations. This approach offers stability and accountability, ensuring that drivers receive fair compensation and adhere to company policies and standards. Additionally, such traditional model of hiring employees is deemed to allow companies to cultivate a dedicated workforce, fostering loyalty, and potentially improving customer experience.

However, in recent years, an alternative approach has gained significant traction: hiring freelancers or independent contractors to fulfill delivery tasks. This trend has been fueled by the rapid growth of the gig economy and technological advancements that has revolutionized the way goods and services are transported and received. The advent of digital delivery platforms has enable efficient matching of delivery requests with available drivers. It is now possible for customers to place orders from anywhere at any time, using various devices such as computers, smartphones, or tablets. Many restaurants have now contracted with these third-party delivery platforms to utilize their delivery services. This convenience has significantly increased the accessibility and demand of delivery services. Moreover, with the use of freelancers, these platforms can tap into a flexible labor pool, scaling their workforce up or down based on demand fluctuations. Such delivery platforms include Ubereats, Doordash, Grubhub, and Postmates. Hence, the food delivery industry has now become a global market that is worth more than $150 billion (Ahuja et al. 2021) and the demand for convenient and fast delivery is expected to continue to grow.

Nevertheless, the shift towards utilizing freelancers is not without controversy. Critics argue that the gig economy model can lead to precarious working conditions, inadequate benefits, and a lack of worker protections (Breese 2023). Freelancers typically do not receive the same level of social security benefits, healthcare coverage, or job security as employees. Moreover, concerns have been raised regarding the potential for exploitation and unfair treatment of freelancers, as they may lack bargaining power and be subject to arbitrary decisions by the companies they work for. Thus, there are several cities and countries contemplating to regulate the delivery platforms and mandating them to hire employees. For example, the US Biden administration is proposing to classify all food delivery worker as employees, so that the workers are eligible for employment benefits (Cohen 2022). Nevertheless, there are concerns that such regulation can have adverse impact in the industry and thus, there are some lawmakers opposing to such blanket classification (Munhoz and Rainey 2023). Hence, the regulation still remains a largely divisive issue. As platform companies' main revenue stream comes from earning the commission fees from gig worker, any potential regulation will affect the platforms' revenue, leading to potential change in the operational or fee structure of the platforms.

Consequently, in light of the potential regulation as well as operational considerations, a crucial decision for a delivery platform is whether to hire employees or engage freelancers as their workers. Employing workers provides the advantage of centralized control but also entails additional costs, as delivery platforms must bear higher labor costs due to providing employment benefits, insurance, and other employee-related expenses (Hu 2022). On the other hand, utilizing freelancers for delivery imply that the platforms only need to pay the freelancers if there is a demand. However, the availability and the ability of freelancers to serve the platform's users is beyond the platform's control, introducing a potential challenge of ensuring an adequate supply of quality freelancers to meet customer needs. This is particularly important in the food delivery industry, where the on time delivery of the food is expected by the customer (Saad 2021). Furthermore, the different incentive structures associated with each employment mode can impact a worker's motivation, subsequently affecting the platform's service quality and profitability. Therefore, striking the right balance between control, cost-effectiveness, and worker motivation becomes a crucial consideration for delivery platforms in determining their preferred employment approach.

Overall, it is unclear whether it is beneficial for the platform to hire freelancers or employees. There are platforms (e.g., Just Eat) that are planning to switch from an employee model to the freelancer model (Sterling 2023), while others (e.g., Bolt) are planning to switch from the freelancer model to an employee model (Cordina 2022). To this end, we hope to answer the following research questions in this study. Are freelancers better than the employees in terms of the delivery service? What factors affect the performance of the freelancers? When should an online food delivery platform hire freelancers? In this paper, we conducted a field experiment to study the value of utilizing freelancers over employees on a food delivery platform. By examining the trade-off between the efficiency loss incurred by relinquishing centralized control and the motivation of the freelancers to deliver, we derive insights into how a platform should manage employees and freelancers. This research is still on-going and this paper gives us some preliminary insights on the findings of the research.

## 3.2 Literature Review

Our paper is related to two main streams of literature: (i) food delivery platforms and (ii) incentives on gig worker performance.

There have been many theoretic papers that study how delivery platforms can improve their operations (see Benjaafar and Hu (2020) for a comprehensive list of references), with a few that focus explicitly on food delivery platforms. These papers explore areas such as matching (Ulmer et al. 2021, Liu et al. 2023), route optimization (He and Goh 2022), user management (Mai et al. 2023), and contract management (Chen et al. 2022b and Feldman et al. 2023). As food deliver platforms faces uncertainty in both the customer identities and the readiness time of food at restaurants, Ulmer et al. (2021) study how an anticipatory customer assignment policy, which postpones assignment decisions for selected customers, can improve service quality. Chen et al. (2022b) find that food delivery services can change the customer composition of restaurants without necessarily increasing overall demand, and coordinating revenue-sharing contracts or limiting the number of delivery workers can benefit both the restaurant and the food delivery platform. Feldman et al. (2023) further find that coordinating contract that involves a percentage revenue share and fixed fee per delivery order help to protect the restaurant margins, which can address tensions between food delivery platforms and restaurants. To date, there is a noticeable absence of theoretical literature dedicated to examining the issue of worker composition specifically within the context of food delivery platforms, due to the theoretical difficulty in identifying the differences in the different worker types.

Moreover, there are only scant empirical and experimental papers that study the workers in the food delivery platforms. Using a data from a food delivery platform, Liu et al. (2021) proposes a framework that combines travel-time predictors and order-assignment optimization to improve the on-time performance of last-mile delivery services, showcasing the effectiveness of the integrated models and emphasizing the significance of learning driver behavior from operational data. Xu et al. (2023) examines the impact of earnings, ratings, and penalties on gig workers' working decisions in on-demand delivery platforms using empirical analysis, revealing that ratings and earnings can be substitutes, past penalties discourage work, and workers with higher penalties are more sensitive to earning increases. Our paper contributes to this stream of literature by the workers under different employment mode behave on an online delivery platform through a randomized field experiment. This answers the fundamental question of whether a platform should hire a freelancer or not, and in doing so, we provide insights on how a food delivery platform should manage its workers' composition so as to provide better food delivery service.

Given the vital role of the workers in the operations of delivery platforms, previous research has explored the impact of incentive structure on workers' behavior in gig platforms. Most of the literature has focus on the impact of earnings on the gig workers (Horton and Chilton 2010, Chen 2016, Chen et al. 2022c, Allon et al. 2023), which is not just restricted to food delivery platforms. There are other papers that focus on the other non-monetary factors that affect the gig workers' performance. For example, Dai et al. (2022) examines the impact of experience on worker performance in the on-demand delivery gig platform industry, revealing that while experience improves operational outcomes, low experience can lead to decreased productivity and service quality at an early stage, highlighting the presence of an exploration-exploitation behavioral mechanism. As employee misconduct poses a significant challenge in gig and remote work contexts, Burbano and Chiles (2022) explore how gig employers can mitigate misconduct through organizational value communication and the credible threat of monitoring. They find that while value communication reduces misconduct, the effect is diminished when workers are aware of monitoring due to decreased trust. Cameron and Rahman (2022) explore the relationship between the platform's algorithmic control and worker's covert resistance to the platform's control. Their study exposes the shortcomings of platforms' heavy reliance on algorithmically mediated customer control by highlighting the ways in which workers' daily interactions with customers can subtly influence and manipulate algorithms, often without detection by the platforms themselves. Our work, therefore, contributes to this emerging stream of literature by examining how the different incentive structure between a freelancer and an employee, affect the workers' motivation to deliver and the workers' order prioritization rule that is beyond the control of the platform.

## 3.3 Experimental Design

### 3.3.1 Research Setting

We collaborate with an online food delivery platform in a major city. This delivery platform is the first platform to operate in the city, and thus, has captured the majority share of the city's food delivery market. This platform employs its own fleet of delivery riders, and has recently allowed freelancers to come onboard as delivery riders. To use the platform's service, a customer orders his food through a mobile application and the order is routed to the restaurant that is onboard the platform's terminal. The restaurant will then work to complete the order and after the order is completed, the platform is notified of its completion. As part of the experiment, the platform will then randomly assign the order to a freelancer dispatch station or an employee dispatch station. If the order is assigned to a freelancer dispatch station, it will push out the availability of that order to the freelancers that are using the platform's mobile application for riders. The freelancer will have to decide whether to get the order and the order is assigned to the freelancer that is the fastest to click and accept the order. If the order is assigned to an employee dispatch station, the platform will assign an available employee to handle the order. After the order is accepted by the rider (freelancer or employee), the rider will work towards picking up the order from the restaurant and delivering the order to the customer.

### 3.3.2 Data and Randomization Checks

Our data, which is anonymized and provided by the platform, consists of two datasets: the dataset for employees and the dataset for freelancers. The data contains the following information: the order ID, customer ID, restaurant ID, rider ID, time information, pick-up distance, delivery distance etc. Till date, there are about more than 200 freelancers and more than 400 employees registered on the platform.

For the analysis, we look at a period of about more than 2 weeks of data in November 2022. We restrict our data to orders that have the value of less than 180 dollars and pick-up distance of less than 0.5km, as the experiment is restricted to these orders. This leave us with about more than 10,000 observations. Figure 3.1 shows the distribution of the number of orders across the day.

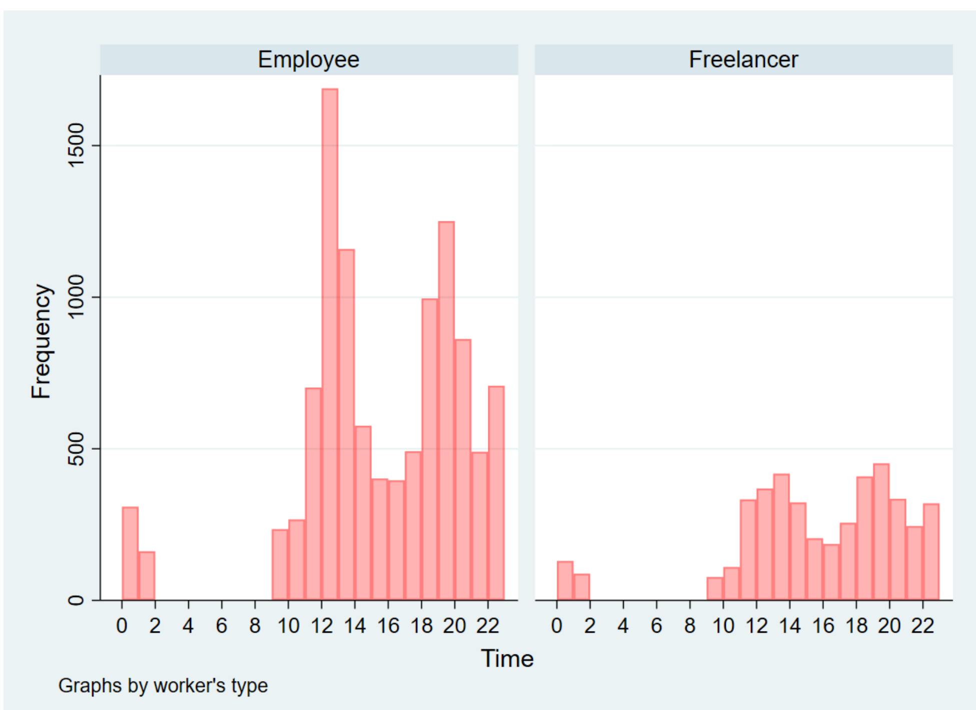



Figure 3.1: Distribution of the orders across the day during the experiment period.

## 3.4 Analysis

Table 3.1 provides an overall summary of key variables analyzed in our study, offering valuable insights into the comparison between employees and freelancers in terms of order handling. We first use the data to confirm the randomness with which the orders were assigned to either the employee or the freelancer groups. The randomization checks (see the first three rows of Table 3.1) confirm that the assignment is random over several key user attributes: (1) the order amount; (2) expected completion time; and (3)the restaurant duration.

Table 3.1: Overall summary statistics of the rider's performance.

| | (1) Employee | | (2) Freelancer | | t-test |
|---|---|---|---|---|---|
| | mean | sd | mean | sd | p-value |
| Order amount ($) | 78.71 | 34.75 | 77.93 | 33.73 | 0.25 |
| Expected completion time (min) | 50.41 | 9.25 | 50.67 | 10.70 | 0.16 |
| Restaurant time (min) | 13.94 | 8.99 | 13.73 | 10.07 | 0.24 |
| Order time (min) | 12.97 | 7.56 | 14.52 | 7.94 | 0.00 |
| Pick-up time (min) | 7.29 | 5.47 | 8.51 | 5.94 | 0.00 |
| Delivery time (min) | 5.22 | 4.60 | 5.46 | 5.10 | 0.01 |
| Pick-up distance (km) | 0.70 | 0.54 | 0.76 | 0.51 | 0.00 |
| Delivery distance (km) | 0.34 | 0.12 | 0.34 | 0.12 | 0.94 |
| On-time | 0.94 | 0.24 | 0.96 | 0.20 | 0.00 |
| Propensity of order batching | 0.51 | 0.50 | 0.34 | 0.48 | 0.00 |
| Observations | 9220 | | 3761 | | |

From the data presented in Table 3.1, it is evident that employees outperform freelancers in terms of order completion time. The average time taken by employees to complete an order is approximately 13 minutes, whereas freelancers take around 14 minutes. There are several justifications for this discrepancy based on the nature of the platform and the characteristics of the two groups.

Firstly, the platform, being centralized, has better control and awareness of its employees. This allows the platform to strategically assign an employee who is already in close proximity to the pick-up location, resulting in faster order handling. In contrast, freelancers who are geographically closer may not always have the opportunity to snatch the optimal order when it becomes available to the freelancer pool. This is evident by longer pick-up distance for the freelancers (i.e., 0.77 km for the freelancers and 0.70 km for the employees) as shown in Table 3.1. This lack of centralized control and coordination can contribute to the slightly longer completion time for freelancers. Secondly, employees tend to handle orders in batches, which significantly improves their efficiency in clearing multiple orders simultaneously. By bundling orders together, employees can optimize their route planning and minimize travel time between pick-up and delivery locations. This batch processing approach enables employees to spend less time overall on order handling compared to freelancers, who may tend to handle orders individually and are not able to benefit from this optimization strategy. Hence, the observed differences in order completion time between employees and freelancers can be attributed to the platform's centralized control and awareness, and employees' ability to handle orders in batches. These factors collectively contribute to the superior performance of employees in terms of order handling speed.

Nevertheless, it is worth noting that the on-time performance of an employee is about 0.94 while the on-time performance of a freelancer is about 0.96. The on-time performance is a binary variable, where 1 implies that the rider is able to deliver the food before the customer's expected completion time and 0 otherwise. Thus, the table shows that the freelancers are more capable of satisfying the customer's expected completion time since they have a higher value of on-time performance. A possible reason for this result is because the freelancers may have a strong sense of personal accountability due to them being self-employed. This personal accountability serves as a driving force, compelling them to uphold punctuality and fulfill food deliveries within the promised time frame.

This heightened sense of accountability and responsibility for their own work may result in freelancers adopting a different order prioritization rule when managing their workload. For example, freelancers may prioritize orders based on their urgency, ensuring that time-sensitive deliveries are completed promptly. In contrast, employees may prioritize orders based on optimizing delivery routes, aiming for the shortest overall travel distance. This distinction in prioritization strategies may explain the slightly longer delivery times and yet greater on-time performance observed for the freelancers. They prioritize meeting each order's deadline and ensuring customer satisfaction, while employees may not place as much emphasis on these factors and focus solely on completing their assigned tasks. It is important to note that while the preliminary analysis provides insights into the potential reasons for the freelancer's punctuality, further analysis is still on-going to establish a comprehensive understanding of the underlying factors.

## 3.5 Remarks

In this preliminary study, our objective was to gain insights into the performance of riders employed under different modes of employment on a food delivery platform. This analysis aimed to shed light on the worker composition that is most suitable for the platform. Our findings revealed that employing workers as employees offers the advantage of centralized control, which contributes to improved efficiency. On the other hand, freelancers exhibit a superior service quality, particularly in terms of punctuality.

This study serves as a starting point for further research and analysis in this area. Our findings not only contribute to the existing literature but also provide valuable insights for policymakers and platform operators, enabling them to make informed decisions regarding worker composition strategies. Moreover, it offers a foundation for future research and discussions surrounding the optimization of employment models, with the ultimate goal of enhancing worker well-being, platform performance, and overall industry sustainability.

APPENDIX A

# APPENDIX OF CHAPTER 1

## A.1 Examples of Platform Dispute Policies

Figure A.1: The dispute procedure of a traditional online labor platform (Source: PeoplePerHour).

### 7. Disputes

PPH encourage our Freelancers and Buyers to try and resolve any disagreements between themselves. However should that not be possible PPH Customer Services can provide Dispute resolution.

A Dispute can be raised:

a. by the Freelancer manually after a Buyer has rejected an invoice;

To raise a dispute, the Freelancer is required to pay a non-refundable fee as per section 8.2

Disputes are available to Freelancers that have qualified as trusted members of the PPH community.

For Invoice Disputes specifically, the amounts taken into consideration for the Dispute are the lower of the escrow balance or invoice amount.

If the amount disputed is £100 (or €130 or USD $160) or above, PPH may reach out to both parties in order to mediate and try and bring the Dispute to resolution.

PPH will aim to make a resolution decision on behalf of both parties within seven (7) days. If a mutual resolution has already been agreed between both parties on the workstream, then the dispute will either be cancelled or resolved in line with the mutual agreement.

Figure A.2: The dispute procedure of an emerging online labor platform (Source: LibertyLance).

Figure A.3: The payout of the tribunal of an emerging online labor platform (Source: Ethearnal).

*On top of that, this is another initiative for people to hold tokens, since they can use them to earn money by moderating.*

When they decide the winning side in the dispute by simple majority (51%), the rep at stake of the losing side is distributed proportionally to the moderators based on THEIR rep at stake. ONLY THE MODERATORS WHO VOTED WITH THE MAJORITY (the winning decision) get rep tokens. The mods that voted with the minority lose their stake to the winning side of the dispute. The logic is that, since they tried to rule unfairly against him, but he turned out to be right, he deserves some rep. WHAT IS FAIR IS DECIDED BY THE VOTE OF THE MAJORITY. This is necessary to give moderators an incentive to act justly. The mods who failed to vote within the determined timeframe lose their rep at stake. This will eliminate non-active mods automatically since they will be losing their rep at stake each time until there is none left and they can't be selected for mods anymore.

Figure A.4: The dispute procedure of a traditional online labor platform with double-sided dispute fee (Source: Freelancer.com).

**Milestone Dispute Resolution Process**

- **STAGE 1 - Identifying the issue**

  The complainant should select the Project and the Milestone payment or payments to be disputed. A User could contest all the Milestones related to a single project in one dispute.

  After which, a description of the issue and an explanation of why the dispute is being opened should be given. From this stage until Stage 3, users are encouraged to attach any files that could support their claims.

  Finally, the complainant is requested to enter the amount he or she is prepared to pay for the Project (if a Buyer) or wish to get paid for the Project (if a Seller). The amount could be between 0 and the total amount of the Milestone Payment(s) in question.

- **STAGE 2 - Negotiations**

  At this stage, either party can negotiate for partial compensation, or (after a period of time) choose to have Freelancer's Dispute Team arbitrate the dispute. Both parties will have the opportunity to tell their side of the story and also negotiate terms to resolve the issue between themselves.

  Only the party who originally filed for the dispute can cancel the dispute. If the issue cannot be resolved through negotiation, either party can choose to pay the Arbitration Fee to have the dispute arbitrated by the Dispute Team. The Arbitration Fee will be refunded if the dispute is either settled through mutual agreement or cancelled before reaching arbitration.

- **STAGE 3 - Final Offers and Evidence**

  After one of the involved parties has paid the Arbitration Fee, the other party has 4 days to also pay the fee. Either party still has the option in this period to negotiate with the other party.

  If the responding party does not pay the arbitration fee within the 4 days, the result will be in favour of the party who escalated the dispute into arbitration first.

  If a solution is found before the responding party pays the fee, the party who paid the Arbitration Fee will be refunded this fee.

  Stage 3 is the last stage where both Users can submit their final evidence to support their case. After Stage 3, the involved parties are no longer allowed to submit evidence. The dispute will be resolved based upon the evidence provided through the Dispute System, or that is otherwise available to the Dispute Team, such as the project description and correspondence between the parties.

  Once the dispute has proceeded to Stage 4, further evidence will no longer be accepted.

- **STAGE 4 - Arbitration**

  At Stage 4, the Dispute Team will review all evidence and other information provided to reach a decision (usually within 48 hours). Dispute verdicts are final, binding, and irreversible. The party who wins the dispute will be refunded their Arbitration Fee.

  In the event that one of the parties of the Dispute has paid the Arbitration Fee, the other party will be given 4 days to pay the Arbitration Fee to move into Arbitration, and failure to do such will close the dispute by default, in favor of the party who initiated stage 4, with the arbitration fee initially paid refunded.

## A.2 Proofs of Section 1.4 (Centralized Dispute System)

*Proof of Lemma 1.1* For a given freelancer's quality level $q$, the platform receives a signal of $x = q + \sigma\epsilon$ and compares it with its threshold $k$. Thus, the probability of the freelancer winning the dispute is $h(q,k) = P(x \geq k) = P(\epsilon \geq \frac{k-q}{\sigma}) = \frac{q-k+\sigma}{2\sigma}$.

It is easy to see that $h(q,k) \leq 1$ if $k - \sigma \leq q \leq k + \sigma$. In this case, from Equation (1.1), the platform's utility if dispute occurs is

$$\begin{aligned}\Pi(k,f) &= h(q,k)\gamma p + f - \theta(k-y)^2 \\ &= \frac{q-k+\sigma}{2\sigma}\gamma p + f - \theta(k-y)^2,\end{aligned}$$

where the last step follows from substituting $h(q,k)$. Taking the first order condition of the above equation with respect to $k$, we have

$$k^* = y - \frac{\gamma p}{4\theta\sigma}.$$

Hence, $P(x \geq k^*) = \frac{q-k^*+\sigma}{2\sigma}$. Therefore, the probability of the freelancer winning the dispute is

$$\begin{aligned}h^*(q) &= h(q,k^*) \\ &= \begin{cases} 0 & \text{if } q \leq k^* - \sigma, \\ \frac{q-y+\sigma}{2\sigma} + \frac{\gamma p}{8\theta\sigma^2} & \text{if } k^* - \sigma < q < k^* + \sigma, \\ 1 & \text{if } q \geq k^* + \sigma, \end{cases}\end{aligned}$$

which is increasing in $q$, and decreasing in $\theta$ and $y$. □

*Proof of Proposition 1.1* Proposition 1.1 can be proven by backward induction based on the decision tree in Figure 1.1.

At Stage 6, the platform makes a decision on the dispute, which will only occur if the client has rejected the freelancer's work and the freelancer has initiated the dispute. Based on Lemma 1.1, the freelancer wins the dispute with probability $h^*(q)$ and loses with probability $1 - h^*(q)$.

At Stage 5, the freelancer makes the decision on whether to initiate the dispute, which will only occur if the client has rejected the freelancer's work. Based on Equation (1.2), the freelancer's utility is

$$U_f(q) = \begin{cases} -\alpha q^2 + h^*(q)(1-\gamma)p - f & \text{if dispute is initiated,} \\ -\alpha q^2 & \text{if dispute is not initiated.} \end{cases}$$

Therefore, the freelancer initiates the dispute if $h^*(q)(1-\gamma)p - f \geq 0$, and does not initiate the dispute otherwise.

At Stage 4, the client decides whether to accept or reject the freelancer's work. Based on Equation (1.3), if the client accepts the freelancer's work, her utility is

$$U_c(p) = q - p.$$

If the client rejects the freelancer's work, her utility is

$$U_c(p) = \begin{cases} q - h^*(q)p & \text{if } h^*(q)(1-\gamma)p - f \geq 0, \\ q & \text{if } h^*(q)(1-\gamma)p - f < 0. \end{cases}$$

Therefore, if $h^*(q)(1-\gamma)p - f \geq 0$, the client accepts if $h^*(q) = 1$ and rejects if $h^*(q) < 1$. If $h^*(q)(1-\gamma)p - f < 0$, the client always rejects since $q \geq q - h^*(q)p \geq q - p$. The client's utility is then given by

$$U_c(p) = \begin{cases} q - p & \text{if } h^*(q) = 1 \text{ and } h^*(q)(1-\gamma)p - f \geq 0, \\ q - h^*(q)p & \text{if } h^*(q) < 1 \text{ and } h^*(q)(1-\gamma)p - f \geq 0, \\ q & \text{if } h^*(q)(1-\gamma)p - f < 0. \end{cases}$$

At Stage 3, the freelancer decides whether to participate or not and chooses his quality level if he participates. If $h^*(q)(1-\gamma)p - f < 0$, the client always rejects and the freelancer does not initiate the dispute. Thus, the freelancer does not participate if $h^*(q)(1-\gamma)p - f < 0$, which is equivalent to choosing $q^* = 0$. If

$h^*(q)(1-\gamma)p - f \geq 0$, the freelancer's utility is

$$U_f(q) = \begin{cases} -\alpha q^2 + (1-\gamma)p & \text{if } h^*(q) = 1, \\ -\alpha q^2 + h^*(q)(1-\gamma)p - f & \text{if } h^*(q) < 1. \end{cases}$$

Note that when $h^*(q) = 0$, the freelancer's utility is negative. Thus, from Lemma 1.1, $q \leq k^* - \sigma$ cannot be an equilibrium.

If $h^*(q) = 1$, we have $q \geq k^* + \sigma = y + \sigma - \frac{\gamma p}{4\sigma\theta}$ from Lemma 1.1. Since the freelancer's utility is decreasing in $q$, he chooses the lowest possible $q$ such that

$$q^* = y + \sigma - \frac{\gamma p}{4\sigma\theta}. \tag{A.1}$$

Therefore, the freelancer's utility is $U_{f,1} = -\alpha(y + \sigma - \frac{\gamma p}{4\sigma\theta})^2 + (1-\gamma)p$.

If $h^*(q) < 1$, we have $h^*(q) = \frac{q-y+\sigma}{2\sigma} + \frac{\gamma p}{8\theta\sigma^2}$ from Lemma 1.1 and thus, the freelancer's utility is concave in $q$. The freelancer chooses $q$ based on the first order condition of his utility such that

$$q^* = \frac{(1-\gamma)p}{4\sigma\alpha}. \tag{A.2}$$

Therefore, the freelancer's utility is $U_{f,2} = -\alpha(\frac{(1-\gamma)p}{4\sigma\alpha})^2 + h^*(\frac{(1-\gamma)p}{4\sigma\alpha})(1-\gamma)p - f$.

Thus, the freelancer does not initiate the dispute if

$$\begin{aligned} & U_{f,1} - U_{f,2} \\ =& \frac{-\alpha^2(\gamma p - 4\sigma\theta(\sigma+y))^2 + 2\alpha\theta\left(8f\sigma^2\theta - (1-\gamma)p(\gamma p - 4\sigma\theta(\sigma+y))\right) - (1-\gamma)^2p^2\theta^2}{16\alpha\sigma^2\theta^2} \\ \geq& 0. \end{aligned}$$

Note that the quality chosen in Equation (A.2) is equal to that in Equation (A.1) (i.e., $\frac{(1-\gamma)p}{4\sigma\alpha} = y + \sigma - \frac{\gamma p}{4\sigma\theta}$) at $\alpha = \frac{(1-\gamma)p\theta}{4\sigma\theta(y+\sigma)-\gamma p}$. If $\alpha \leq \frac{(1-\gamma)p\theta}{4\sigma\theta(y+\sigma)-\gamma p}$, the quality chosen based on Equation (A.2) is greater than Equation (A.1). In this case, we have $U_{f,1} \geq U_{f,2}$, since $h^*(q) = 1$ for $q \geq k^* + \sigma = y + \sigma - \frac{\gamma p}{4\sigma\theta}$ from Lemma 1.1 and the quality cost under $U_{f,2}$ is higher. Thus, the dispute is not initiated. Moreover, notice that the numerator of $U_{f,1} - U_{f,2}$ is quadratic downwards in terms of $\alpha$ and hence, there exists two roots to $U_{f,1} - U_{f,2} = 0$. Since at $\alpha = \frac{(1-\gamma)p\theta}{4\sigma\theta(y+\sigma)-\gamma p}$, $U_{f,1} - U_{f,2} \geq 0$. Thus, the other root must be greater than $\alpha = \frac{(1-\gamma)p\theta}{4\sigma\theta(y+\sigma)-\gamma p}$. Therefore, there exists a threshold $\underline{\alpha}_c \geq \frac{(1-\gamma)p\theta}{4\sigma\theta(y+\sigma)-\gamma p}$, such that $U_{f,1} - U_{f,2} \geq 0$ if $\alpha \leq \underline{\alpha}_c$. Hence, if $h^*(q)(1-\gamma)p - f \geq 0$, the freelancer's optimal quality level is

$$q^* = \begin{cases} y + \sigma - \frac{\gamma p}{4\theta\sigma} & \text{if } \alpha \leq \underline{\alpha}_c, \\ \frac{(1-\gamma)p}{4\sigma\alpha} & \text{if } \alpha > \underline{\alpha}_c. \end{cases}$$

Moreover, the freelancer participates if $U_f \geq 0$ and does not participate if $U_f < 0$.

At Stage 2, the client decides whether to participate or not and if she participates, she chooses the price to offer to the freelancer, subject to the freelancer's individual rationality constraint.

(a) If $\alpha \leq \underline{\alpha}_c$ and $h^*(q^*)(1-\gamma)p - f \geq 0$, we have $h^*(q^*) = 1$ and $q^* = y + \sigma - \frac{\gamma p}{4\theta\sigma}$. As dispute does not occur in this case, the client's problem is

$$\begin{aligned} \max_{p \geq 0} \quad & q^* - p, \\ \text{s.t.} \quad & -\alpha(q^*)^2 + (1-\gamma)p \geq 0. \end{aligned}$$

Since the client's utility is decreasing in $p$, $p$ is chosen such that $(1-\gamma)p - f \geq 0$ and $-\alpha(q^*)^2 + (1-\gamma)p \geq 0$ for the freelancer to participate. Therefore, $p^* = \max(\frac{\alpha\left(y+\sigma-\frac{\gamma p^*}{4\theta\sigma}\right)^2}{1-\gamma}, \frac{f}{1-\gamma})$.

(b) If $\alpha > \underline{\alpha}_c$ and $h^*(q^*)(1-\gamma)p - f \geq 0$, we have $h^*(q^*) < 1$ and $q^* = \frac{(1-\gamma)p}{4\sigma\alpha}$. As dispute occurs in this case, the client's problem is

$$\begin{aligned} \max_{p \geq 0} \quad & q^* - h^*(q^*)p, \\ \text{s.t.} \quad & -\alpha(q^*)^2 + h^*(q^*)(1-\gamma)p - f \geq 0. \end{aligned}$$

We first consider the case where the individual rationality constraint of the freelancer is binding. Let $\bar{p}_c$ be the price at which the individual rationality constraint of the freelancer is binding, i.e., $\bar{p}_c$ is the solution of $U_f(q^*) =$

$-\alpha(q^*)^2 + h^*(q^*)(1-\gamma)\bar{p}_c - f = 0$. Using the Envelope Theorem, $\frac{\partial U_f}{\partial \bar{p}_c} = h^*(q^*)(1 - \gamma) + \frac{\gamma}{8\theta\sigma^2}(1-\gamma)\bar{p}_c > 0$ and $\frac{\partial U_f}{\partial f} = -1 < 0$. As such, using the Implicit Function Theorem,

$$\frac{\partial \bar{p}_c}{\partial f} = -\frac{\frac{\partial U_f}{\partial f}}{\frac{\partial U_f}{\partial \bar{p}_c}} > 0. \tag{A.3}$$

We next define $\hat{p}_c$ as the solution to the unconstrained client's problem. Taking the derivative of the client's utility, we have

$$\begin{aligned}\frac{\partial U_c}{\partial p} &= \frac{\partial q^*}{\partial p} - \left[\left(\frac{\partial h^*(q^*)}{\partial q^*}\frac{\partial q^*}{\partial p} + \frac{\partial h^*(q^*)}{\partial p}\right)p + h^*(q^*)\right] \\ &= \frac{1-\gamma}{4\sigma\alpha} - \left[\left(\frac{1-\gamma}{8\sigma^2\alpha} + \frac{\gamma}{8\theta\sigma^2}\right)p + h^*(q^*)\right],\end{aligned}$$

where the last step follows from differentiating Equation (A.2) and differentiating $h^*(q^*)$. Therefore, $\frac{\partial U_c}{\partial p}\Big|_{p=0} = \frac{1-\gamma}{4\sigma\alpha} - h^*(q^*)$ is positive as $h^*(q^*) \le \frac{q^*}{p} = \frac{1-\gamma}{4\sigma\alpha}$ from the individual rationality constraint of the client (i.e., $U_c \ge 0$) and Equation (A.2). Thus, we must have $\hat{p}_c \ge 0$ if the client participates.

Since $\bar{p}_c$ is increasing in $f$ from Equation (A.3) and $\hat{p}_c$ is constant in $f$, there exists a threshold $\underline{f}_c$ such that $\hat{p}_c = \bar{p}_c$ and

$$p^* = \begin{cases} \hat{p}_c & \text{if } f \le \underline{f}_c, \\ \bar{p}_c & \text{if } f > \underline{f}_c. \end{cases}$$

At $f = \underline{f}_c$, rearranging the binding individual rationality constraint of the freelancer, we obtain $\bar{p}_c = \frac{\underline{f}_c + \alpha(q^*)^2}{h^*(q^*)(1-\gamma)}$, which is increasing in $\underline{f}_c$. Therefore, the client's utility is $U_c = q^* - \frac{\underline{f}_c + \alpha(q^*)^2}{(1-\gamma)}$, which is non-negative if and only if $\underline{f}_c \le (1-\gamma)(q^*) - \alpha(q^*)^2$. Therefore, if $\underline{f}_c \le (1-\gamma)(q^*) - \alpha(q^*)^2$, the client's offer price is

$$p^* = \begin{cases} \hat{p}_c & \text{if } f \le \underline{f}_c, \\ \frac{f + \alpha(q^*)^2}{h^*(q^*)(1-\gamma)} & \text{if } f > \underline{f}_c. \end{cases} \tag{A.4}$$

Moreover, the client participates if $q^* - h^*(q^*)p^* \geq 0$, and does not participate if $q^* - h^*(q^*)p^* < 0$. In both cases, the individual rationality constraint of the freelancer depends on the dispute fee $f$.

At Stage 1, the platform chooses the dispute fee $f$ while satisfying the individual rationality constraints of the client and the freelancer.

(a) Recall from previous analyses that if $\alpha \leq \underline{\alpha}_c$, dispute does not occur. The freelancer chooses quality $q^* = y + \sigma - \frac{\gamma p^*}{4\theta\sigma}$ and the client offers price $p^* = \max(\frac{\alpha(y+\sigma-\frac{\gamma p^*}{4\theta\sigma})^2}{1-\gamma}, \frac{f}{1-\gamma})$. Thus, the platform will achieve a utility of $\Pi(f) = \gamma p^* = \gamma \max(\frac{\alpha(y+\sigma-\frac{\gamma p^*}{4\theta\sigma})^2}{1-\gamma}, \frac{f}{1-\gamma})$. Based on Equation (1.4), the platform's optimization problem is as follows:

$$\max_{f\geq 0} \quad \gamma \max\left(\frac{\alpha(y+\sigma-\frac{\gamma p^*}{4\theta\sigma})^2}{1-\gamma}, \frac{f}{1-\gamma}\right),$$

$$\text{s.t.} \quad (y+\sigma-\frac{\gamma p^*}{4\theta\sigma}) - \max\left(\frac{\alpha(y+\sigma-\frac{\gamma p^*}{4\theta\sigma})^2}{1-\gamma}, \frac{f}{1-\gamma}\right) \geq 0, \tag{A.5}$$

$$-\alpha(y+\sigma-\frac{\gamma p^*}{4\theta\sigma})^2 + (1-\gamma)\max\left(\frac{\alpha(y+\sigma-\frac{\gamma p^*}{4\theta\sigma})^2}{1-\gamma}, \frac{f}{1-\gamma}\right) \geq 0, \tag{A.6}$$

where Equation (A.5) is the individual rationality constraint of the client, and Equation (A.6) is the individual rationality constraint of the freelancer.

Notice from the above problem formulation that the case of $\frac{f}{1-\gamma} \leq \frac{\alpha(y+\sigma-\frac{\gamma p^*}{4\theta\sigma})^2}{1-\gamma}$ is equivalent to $\frac{f}{1-\gamma} = \frac{\alpha(y+\sigma-\frac{\gamma p^*}{4\theta\sigma})^2}{1-\gamma}$. We thus focus on $\frac{f}{1-\gamma} \geq \frac{\alpha(y+\sigma-\frac{\gamma p^*}{4\theta\sigma})^2}{1-\gamma}$, or equivalently, $f \geq \alpha(y+\sigma-\frac{\gamma p^*}{4\theta\sigma})^2$. In this case, the platform's utility reduces to $\Pi = \frac{\gamma f}{1-\gamma}$, Equation (A.5) reduces to $f \leq (1-\gamma)(y+\sigma-\frac{\gamma p^*}{4\theta\sigma})$, and Equation (A.6) reduces to $f \geq \alpha(y+\sigma-\frac{\gamma p^*}{4\theta\sigma})^2$. Thus, if $\alpha(y+\sigma-\frac{\gamma p^*}{4\theta\sigma})^2 > (1-\gamma)(y+\sigma-\frac{\gamma p^*}{4\theta\sigma})$, or equivalently, $y+\sigma-\frac{\gamma p^*}{4\theta\sigma} > \frac{1-\gamma}{\alpha}$, the problem is infeasible. If $y+\sigma-\frac{\gamma p^*}{4\theta\sigma} \leq \frac{1-\gamma}{\alpha}$, since $\Pi$ is increasing in $f$, we have

$$f^* = (1-\gamma)\left(y+\sigma-\frac{\gamma p^*}{4\theta\sigma}\right), \tag{A.7}$$

which also satisfies $f^* \geq \alpha(y+\sigma-\frac{\gamma p^*}{4\theta\sigma})^2$. Since $p^* = \frac{f}{1-\gamma}$, from Equation (A.7) we have $p^* = (y + \sigma - \frac{\gamma p^*}{4\theta\sigma}) = q^*$. Therefore, $p^*$ is given by

$$p^* = \frac{4\sigma\theta(y+\sigma)}{\gamma + 4\sigma\theta},$$

and $q^*$ is given by

$$q^* = \frac{4\sigma\theta(y+\sigma)}{\gamma + 4\sigma\theta}.$$

Hence, the platform's equilibrium utility is $\Pi^* = \gamma p^* = \frac{4\gamma\sigma\theta(y+\sigma)}{\gamma+4\sigma\theta}$.

Finally, we derive the threshold $\underline{\alpha}_c$. Recall that the freelancer does not initiate the dispute if $U_{f,1} - U_{f,2} \geq 0$. As $p^* = \frac{f^*}{1-\gamma}$, if the freelancer initiates the dispute (i.e., choosing $q < \frac{4\sigma\theta(y+\sigma)}{\gamma+4\sigma\theta}$), the freelancer's utility is $U_{f,2} = -\alpha q^2 + h^*(q)(1-\gamma)p^* - f^* = -\alpha q^2 - (1 - h^*(q))f^* \leq 0$. Therefore, the condition $U_{f,1} - U_{f,2} \geq 0$ is always satisfied by the freelancer's individual rationality constraint (i.e., Equation (A.6)). Thus, the condition can be re-expressed as $\alpha \leq \underline{\alpha}_c = \frac{1-\gamma}{q^*} = \frac{(1-\gamma)(\gamma+4\sigma\theta)}{4\sigma\theta(y+\sigma)}$.

(b) Recall from previous analyses that if $\alpha > \underline{\alpha}_c$, dispute occurs. The freelancer chooses quality $q^* = \frac{(1-\gamma)p^*}{4\sigma\alpha}$ and the client offers price $p^*$ based on Equation (A.4). Based on Equation (1.4), the platform's optimization problem is as follows:

$$\begin{aligned} \max_{f \geq 0} \quad & h^*(q^*)\gamma p^* + f - \theta(k^* - y)^2, \\ \text{s.t.} \quad & q^* - h^*(q^*)p^* \geq 0, && \text{(A.8)} \\ & -\alpha(q^*)^2 + h^*(q^*)(1-\gamma)p^* - f \geq 0, && \text{(A.9)} \end{aligned}$$

where Equation (A.8) is the individual rationality constraint of the client, and Equation (A.9) is the individual rationality constraint of the freelancer. From Lemma 1.1, $k^* = y - \frac{\gamma p^*}{4\theta\sigma}$. Thus, $\Pi$ can be equivalently expressed as $\Pi(f) = h^*(q^*)\gamma p^* + f - \frac{\gamma^2 (p^*)^2}{16\theta\sigma^2}$.

Recall from Stage 2(b) that if $\underline{f}_c \leq (1-\gamma)(q^*) - \alpha(q^*)^2$, $U_c \geq 0$. Since $\frac{\partial U_c}{\partial f}\Big|_{p=\bar{p}_c} = \frac{\partial U_c}{\partial p}\Big|_{p=\bar{p}_c} \frac{\partial \bar{p}_c}{\partial f} < 0$, $U_c$ is decreasing in $f$. Thus, there exists a threshold $\bar{f}_c$, where

$\bar{f}_c > \underline{f}_c$, such that $U_c \geq 0$ if and only if $f \leq \bar{f}_c$. Moreover, we have shown previously that $U_c = 0$ if $f = (1-\gamma)(q^*) - \alpha(q^*)^2$, and thus, $\bar{f}_c = (1-\gamma)q^* - \alpha(q^*)^2$. Therefore, there are three possible cases of $f$, which are defined as follows:

$$\text{Case b.1: } f \leq \underline{f}_c < \bar{f}_c \Rightarrow U_f \geq 0 \text{ and } U_c \geq 0,$$
$$\text{Case b.2: } \underline{f}_c < f \leq \bar{f}_c \Rightarrow U_f = 0 \text{ and } U_c \geq 0,$$
$$\text{Case b.3: } f > \bar{f}_c \Rightarrow \text{No contracting occurs.}$$

Under Case b.1, since $f \leq \underline{f}_c$, $p^* = \hat{p}_c$ and $q^*$ are both constant in $f$. This implies that the platform's utility $\Pi$ is increasing in $f$. As such, $f^* = \underline{f}_c$, under which $U_f = 0$ and $U_c > 0$. Under Case b.2, since $f > \underline{f}_c$ and $f \leq \bar{f}_c$, $p^* = \bar{p}_c$ and $q^*$ both depend on $f$. The derivative of $h^*(q^*)$ with respect to $f$ is given by

$$\begin{aligned}\frac{\partial h^*(q^*)}{\partial f} &= \frac{\partial h^*(q^*)}{\partial q^*}\frac{\partial q^*}{\partial f} + \frac{\partial h^*(q^*)}{\partial \bar{p}_c}\frac{\partial \bar{p}_c}{\partial f}\\ &= \left[\frac{\partial h^*(q^*)}{\partial q^*}\frac{\partial q^*}{\partial \bar{p}_c} + \frac{\partial h^*(q^*)}{\partial \bar{p}_c}\right]\frac{\partial \bar{p}_c}{\partial f}\\ &= \left(\frac{1-\gamma}{8\sigma^2\alpha} + \frac{\gamma}{8\theta\sigma^2}\right)\frac{\partial \bar{p}_c}{\partial f}, \end{aligned} \tag{A.10}$$

where the second step follows from applying the chain rule to $\frac{\partial q^*}{\partial f}$, and the last step follows from differentiating Equation (A.2) and differentiating $h^*(q^*)$. The derivative of $\Pi$ with respect to $f$ is given by

$$\begin{aligned}\frac{\partial \Pi}{\partial f} &= \gamma\left[\frac{\partial h^*(q^*)}{\partial f}\bar{p}_c + h^*(q^*)\frac{\partial \bar{p}_c}{\partial f}\right] + 1 - \frac{\gamma^2\bar{p}_c}{8\theta\sigma^2}\frac{\partial \bar{p}_c}{\partial f}\\ &= \gamma\left[\left(\frac{1-\gamma}{8\sigma^2\alpha} + \frac{\gamma}{8\theta\sigma^2}\right)\frac{\partial \bar{p}_c}{\partial f}\bar{p}_c + h^*(q^*)\frac{\partial \bar{p}_c}{\partial f}\right] + 1 - \frac{\gamma^2\bar{p}_c}{8\theta\sigma^2}\frac{\partial \bar{p}_c}{\partial f}\\ &= \gamma\left[\frac{(1-\gamma)\bar{p}_c}{8\sigma^2\alpha} + h^*(q^*)\right]\frac{\partial \bar{p}_c}{\partial f} + 1\\ &> 0, \end{aligned}$$

where the second step follows from substituting $\frac{\partial h^*(q^*)}{\partial f}$ with Equation (A.10), and the last step follows from $\frac{\partial \bar{p}_c}{\partial f} > 0$ based on Equation (A.3). Since $\Pi$ is increasing in $f$ throughout Case b.1 and Case b.2, the optimal dispute fee is $f^* = \bar{f}_c$, under which $U_f^* = U_c^* = 0$. Consequently, the optimal dispute fee is

$$f^* = (1-\gamma)q^* - \alpha(q^*)^2, \tag{A.11}$$

and from the binding individual rationality constraint of the client in Equation (A.8), we obtain the client's equilibrium the offer price is $p^* = \frac{q^*}{h^*(q^*)}$. From Equation (A.2), we obtain $q^* = \frac{(1-\gamma)p^*}{4\alpha\sigma}$. Substituting $q^*$ into Equation (A.8), we have

$$\begin{aligned}
& q^* - h^*(q^*)p^* = 0 \\
\Leftrightarrow\ & q^* - \left(\frac{q^* - y + \sigma}{2\sigma} + \frac{\gamma p^*}{8\theta\sigma^2}\right)p^* = 0 \\
\Leftrightarrow\ & \frac{(1-\gamma)p^*}{4\alpha\sigma} - \left(\frac{\frac{(1-\gamma)p^*}{4\alpha\sigma} - y + \sigma}{2\sigma} + \frac{\gamma p^*}{8\theta\sigma^2}\right)p^* = 0 \\
\Leftrightarrow\ & p^* = \frac{2\sigma\theta(2\alpha(y-\sigma) + (1-\gamma))}{\gamma\alpha + (1-\gamma)\theta},
\end{aligned}$$

where the first step follows from $h^*(q^*) = \frac{q^*-y+\sigma}{2\sigma} + \frac{\gamma p^*}{8\theta\sigma^2}$ and the second step follows from $q^* = \frac{(1-\gamma)p^*}{4\alpha\sigma}$. Therefore, from Equation (A.2), we have

$$q^* = \frac{(1-\gamma)\theta(2\alpha(y-\sigma) + (1-\gamma))}{2\alpha\left(\gamma\alpha + (1-\gamma)\theta\right)},$$

and from Equation (A.11), we have

$$f^* = \frac{(1-\gamma)^2\theta(2\alpha(y-\sigma) + (1-\gamma))(2\alpha(\gamma - \theta(y-\sigma)) + (1-\gamma)\theta)}{4\alpha(\gamma\alpha + (1-\gamma)\theta)^2}. \tag{A.12}$$

Therefore, the platform's utility is

$$\begin{aligned}
\Pi^* =& h^*(q^*)\gamma p^* + f^* - \frac{\gamma^2(p^*)^2}{16\theta\sigma^2} \\
=& \frac{q^* - y + \sigma}{2\sigma}\gamma p^* + f^* + \frac{\gamma^2(p^*)^2}{16\theta\sigma^2} \\
=& \frac{1}{4\alpha(\gamma\alpha + (1-\gamma)\theta)^2}\Big[\theta(2\alpha(y-\sigma) + (1-\gamma))\Big( - 2\gamma^2\alpha^2(y-\sigma) \\
& + (1-\gamma)\alpha((2-\gamma)\gamma - 2\gamma\sigma\theta - 2(1-\gamma)\theta y + 2\sigma\theta) + (1+\gamma)(1-\gamma)^2\theta\Big)\Big],
\end{aligned}$$

where the second step follows from $h^*(q^*) = \frac{q^*-y+\sigma}{2\sigma} + \frac{\gamma p^*}{8\theta\sigma^2}$.

Finally, since $f^* = q^*((1-\gamma) - \alpha q^*) \geq 0$ for contracting to occur, if $\sigma > y$, $f^* = 0$ at $\alpha = \frac{1-\gamma}{2(\sigma-y)}$. If $\sigma \leq y - \frac{\gamma}{\theta}$, from Equation (A.12), $f^* = 0$ at $\alpha = \frac{(1-\gamma)\theta}{2(\theta(y-\sigma)-\gamma)}$. If $y - \frac{\gamma}{\theta} < \sigma \leq y$, $f^* \geq 0$ for all $\alpha$. Therefore, if dispute occurs, there exists a threshold, $\hat{\alpha}_c$, such that $f^* \geq 0$ if and only if $\alpha \leq \hat{\alpha}_c$, where $\hat{\alpha}_c$ is given by

$$\hat{\alpha}_c = \begin{cases} \frac{(1-\gamma)\theta}{2(\theta(y-\sigma)-\gamma)} & \text{if } \sigma \leq y - \frac{\gamma}{\theta}, \\ \infty & \text{if } y - \frac{\gamma}{\theta} < \sigma \leq y, \\ \frac{1-\gamma}{2(\sigma-y)} & \text{if } \sigma > y. \end{cases}$$

If $\alpha > \hat{\alpha}_c$, since the dispute fee has to be non-negative, setting $f^* = 0$ would cause the individual rationality constraint of the freelancer to be violated. We define $\bar{\alpha}_c = \max(\underline{\alpha}_c, \hat{\alpha}_c)$. Contracting occurs in equilibrium if and only if $\alpha \leq \bar{\alpha}_c$. Thus, given that contracting occurs, dispute occurs in equilibrium if and only if $\underline{\alpha}_c < \alpha \leq \bar{\alpha}_c$. □

## A.3 Proofs of Section 1.5 (Decentralized Dispute System)

*Proof of Lemma 1.2* We prove that the switching strategy around $y$ (i.e., voter $i$ votes for the freelancer if $x_i \geq y$ and votes for the client if $x_i < y$) is a Bayesian Nash equilibrium in the voting game. To that end, we suppose all voters but voter $i$ follow a switching strategy around $y$ and show that voter $i$'s best response is to follow the same switching strategy (i.e., $k_i^* = y$). Assume that voter $i$ follows a switching strategy $k_i$ and all the rest of the voters follow a switching strategy around $y$. The proportion of voters that vote for the freelancer is

$$l = \begin{cases} 0 & \text{if } q < y - \sigma, \\ \frac{q-y+\sigma}{2\sigma} & \text{if } y - \sigma \leq q \leq y + \sigma, \\ 1 & \text{if } q > y + \sigma. \end{cases} \tag{A.13}$$

Since the prior is uniform, if voter $i$ receives a signal $x_i$, he knows that the true value of $q$ lies between $x_i - \sigma$ and $x_i + \sigma$, and other voters' signals lie between $x_i - 2\sigma$ and $x_i + 2\sigma$. Moreover, since the noise follows the uniform distribution, the updated probability density distribution that voter $i$ has on $q$ is a uniform distribution with density $\frac{1}{2\sigma}$. Thus, we consider the expected utility from following the switching strategy around $k_i$ under various possible values of $x_i$'s by taking the expectation of voter $i$'s utility given in Equation (1.5) over all the possible values of the proportion of voters that vote for the freelancer, based on his belief on the distribution of the true quality $q$. Let $U_i(x_i, k_i) = \mathbf{E}_l[u_i(x_i, k_i, l)]$.

We first examine the cases where $x_i < y$. If $x_i < y - 2\sigma$, since the true value of $q$ is at most $y - \sigma$, we have $l = 0$ from Equation (A.13). Thus, the voter's expected utility is

$$\begin{aligned} U_i(x_i, k_i) &= \mathbf{1}_{x_i < k_i} \int_{x_i-\sigma}^{x_i+\sigma} \frac{t}{1-l} \frac{1}{2\sigma} \, \mathrm{d}q - t - \xi(k_i - y)^2 \\ &= \mathbf{1}_{x_i < k_i} t - t - \xi(k_i - y)^2, \end{aligned} \tag{A.14}$$

where the last step follows from $l = 0$. In this case, as voter $i$ can only win if he votes for the client (i.e., $x_i < k_i$), voter $i$ always chooses to follow the switching strategy around $y$ to maximize his expected utility in Equation (A.14).

If $y - 2\sigma \leq x_i < y - \sigma$, since the true value of $q$ is at most $y$, we have $l < 0.5$

from Equation (A.13). Thus, the voter's expected utility is

$$
\begin{aligned}
U_i(x_i, k_i) &= \mathbf{1}_{x_i<k_i} \int_{x_i-\sigma}^{x_i+\sigma} \frac{t}{1-l} \frac{1}{2\sigma} \, \mathrm{d}q - t - \xi(k_i - y)^2 \\
&= \mathbf{1}_{x_i<k_i} \left( \int_{\min(y-2\sigma, x_i-\sigma)}^{y-\sigma} \frac{t}{2\sigma} \, \mathrm{d}q + \int_{y-\sigma}^{x_i+\sigma} \frac{t}{1-l} \frac{1}{2\sigma} \, \mathrm{d}q \right) - t - \xi(k_i - y)^2 \\
&= \mathbf{1}_{x_i<k_i} \left( \int_{\min(y-2\sigma, x_i-\sigma)}^{y-\sigma} \frac{t}{2\sigma} \, \mathrm{d}q + \int_{y-\sigma}^{x_i+\sigma} \frac{t}{y+\sigma-q} \, \mathrm{d}q \right) - t - \xi(k_i - y)^2 \\
&= \mathbf{1}_{x_i<k_i} t \left( \frac{y-x_i}{2\sigma} + \ln(2\sigma) - \ln(y - x_i) \right) - t - \xi(k_i - y)^2,
\end{aligned}
\tag{A.15}
$$

where the second step follows from $l = 0$ if $q < y - \sigma$, and the third step follows from substituting in Equation (A.13). In this case, voter $i$ can only win if he votes for the client (i.e., $x_i < k_i$). Thus, voter $i$ chooses to follow the switching strategy around $y$ to maximize his expected utility in Equation (A.15).

If $y - \sigma \leq x_i < y$, since the true value of $q$ can be larger than $y$, we have $0 \leq l \leq 1$ from Equation (A.13). Thus, the voter's expected utility is

$$
\begin{aligned}
U_i(x_i, k_i) =& \mathbf{1}_{x_i \geq k_i} \left( \int_{y}^{x_i+\sigma} \frac{t}{l} \frac{1}{2\sigma} \, \mathrm{d}q \right) + \mathbf{1}_{x_i<k_i} \left( \int_{x_i-\sigma}^{y} \frac{t}{1-l} \frac{1}{2\sigma} \, \mathrm{d}q \right) - t - \xi(k_i - y)^2 \\
=& \mathbf{1}_{x_i \geq k_i} \left( \int_{y}^{x_i+\sigma} \frac{t}{l} \frac{1}{2\sigma} \, \mathrm{d}q \right) + \mathbf{1}_{x_i<k_i} \left( \int_{x_i-\sigma}^{y-\sigma} \frac{t}{2\sigma} \, \mathrm{d}q + \int_{y-\sigma}^{y} \frac{t}{1-l} \frac{1}{2\sigma} \, \mathrm{d}q \right) - t - \xi(k_i - y)^2 \\
=& \mathbf{1}_{x_i \geq k_i} \left( \int_{y}^{x_i+\sigma} \frac{t}{q-y+\sigma} \, \mathrm{d}q \right) + \mathbf{1}_{x_i<k_i} \left( \int_{x_i-\sigma}^{y-\sigma} \frac{t}{2\sigma} \, \mathrm{d}q + \int_{y-\sigma}^{y} \frac{t}{y+\sigma-q} \, \mathrm{d}q \right) \\
& - t - \xi(k_i - y)^2 \\
=& \mathbf{1}_{x_i \geq k_i} t \left( \ln(x_i - y + 2\sigma) - \ln(\sigma) \right) + \mathbf{1}_{x_i<k_i} t \left( \frac{y-x_i}{\sigma} + \ln(2) \right) - t - \xi(k_i - y)^2 \\
=& \begin{cases} t \left( \ln(x_i - y + 2\sigma) - \ln(\sigma) \right) - t - \xi(k_i - y)^2 & \text{if } x_i \geq k_i, \\ t \left( \frac{y-x_i}{\sigma} + \ln(2) \right) - t - \xi(k_i - y)^2 & \text{if } x_i < k_i, \end{cases}
\end{aligned}
\tag{A.16}
$$

where the second step follows from $l = 0$ if $q < y - \sigma$, the third step follows from substituting in Equation (A.13), and the last step follows from re-arranging the terms. In this case, if voter $i$ chooses $k_i < y$, the gain of following the switching strategy around $k_i$ over $y$ if $x_i \geq k_i$ is

$$
\begin{aligned}
& U_i(x_i, k_i) - U_i(x_i, y) \\
=& t\left(\ln(x_i - y + 2\sigma) - \ln(\sigma)\right) - \xi(k - y)^2 - t\left(\frac{y - x_i}{\sigma} + \ln(2)\right) \\
\leq& t\left(\ln(2\sigma) - \ln(\sigma)\right) - \xi(k - y)^2 - t\ln(2) \\
=& -\xi(k - y)^2 \\
<& 0,
\end{aligned}
$$

where the second step follows from substituting in $x_i = y$. Moreover, the gain of following the switching strategy around $k$ over $y$ if $x_i < k$ is

$$
\begin{aligned}
& U_i(x_i, k_i) - U_i(x_i, y) \\
=& t\left(\frac{y - x_i}{\sigma} + \ln(2)\right) - \xi(k_i - y)^2 - t\left(\frac{y - x_i}{\sigma} + \ln(2)\right) \\
=& -\xi(k_i - y)^2 \\
<& 0.
\end{aligned}
$$

Thus, the voter does not choose $k_i < y$. Likewise, if the voter chooses $k_i \geq y$, he will incur a disutility from $\xi(k_i - y)^2$ even though he votes with the majority. Thus, the voter always chooses to follow the switching strategy around $y$ to maximize his expected utility in Equation (A.15). Following a similar approach, we can show that if $x_i \geq y$, voter $i$ always chooses to follow the switching strategy around $y$ in order to maximize his utility.

We next derive the equilibrium probability of the freelancer winning the dispute given that he chooses quality level $q$, $h^+(q)$. Since $h^+(q)$ is given by the proportion of voters that vote for the freelancer, we have

$$
h^+(q) = \begin{cases} 0 & \text{if } q < y - \sigma, \\ \frac{q - y + \sigma}{2\sigma} & \text{if } y - \sigma \leq q \leq y + \sigma, \\ 1 & \text{if } q > y + \sigma. \end{cases}
$$

□

*Proof of Proposition 1.2* We now prove that the switching strategy around $y$ is the unique threshold equilibrium if $\sigma > \sqrt{\frac{t(\frac{1}{2}+\ln(2))}{\xi}}$. To prove this, we show that if $\sigma > \sqrt{\frac{t(\frac{1}{2}+\ln(2))}{\xi}}$, for all $x_i' s$, a voter will choose a switching strategy around $y$ regardless of other voters even if they coordinate on a different threshold than $y$. Suppose all other voters follow a switching strategy around $k$, where $k \neq y$. The proportion of voters that vote for the freelancer is

$$l = \begin{cases} 0 & \text{if } q < k - \sigma, \\ \frac{q-k+\sigma}{2\sigma} & \text{if } k - \sigma \leq q \leq k + \sigma, \\ 1 & \text{if } q > k + \sigma. \end{cases} \tag{A.17}$$

(i) If $x_i < k - 2\sigma$, since the true $q$ is at most $k - \sigma$, we have $l = 0$ from Equation (A.17). For an arbitrary voter $i$, if he chooses $k_i = k$, his expected utility is given by

$$\begin{aligned} U_i(x_i, k) &= \mathbf{1}_{x_i<k} \int_{x_i-\sigma}^{x_i+\sigma} \frac{t}{1-l} \frac{1}{2\sigma} \, \mathrm{d}q - t - \xi(k-y)^2 \\ &= \mathbf{1}_{x_i<k} t - t - \xi(k-y)^2 \\ &= -\xi(k-y)^2 \end{aligned}$$

where the second step follows from $l = 0$ and the last step follows from $x_i < k - 2\sigma < k$. If he chooses $k_i = y$, his expected utility is given by

$$\begin{aligned} U_i(x_i, y) &= \mathbf{1}_{x_i<y} \int_{x_i-\sigma}^{x_i+\sigma} \frac{t}{1-l} \frac{1}{2\sigma} \, \mathrm{d}q - t \\ &= \mathbf{1}_{x_i<y} t - t. \end{aligned}$$

There are two cases to examine: (a) $x_i < y$ and (b) $x_i \geq y$. (a) If $x_i < y$, it is easy to see that $u_i(x_i, y, l) > u_i(x_i, k, l)$ and voter $i$ chooses $k_i = y$. (b) If $x_i \geq y$, the gain of following the switching strategy $y$ is given by

$$\begin{aligned}U_i(x_i, y) - U_i(x_i, k) &= -t + \xi(k-y)^2 \\ &\geq -t + \xi(2\sigma)^2 \\ &\geq 0,\end{aligned}$$

where the second step follows from $y \leq x_i < k - 2\sigma$, and the last step follows from $\sigma > \sqrt{\frac{t(\frac{1}{2}+\ln(2))}{\xi}} > \sqrt{\frac{t}{4\xi}}$. Thus, $u_i(x_i, y, l) > u_i(x_i, k, l)$ and voter $i$ chooses $k_i = y$. Hence, for $x_i < k - 2\sigma$, the voters follow a switching strategy around $y$.

(ii) If $k - 2\sigma \leq x_i < k - \sigma$, since the true $q$ is at most $k$, we have $l < 0.5$ from Equation (A.17). For an arbitrary voter $i$, if he chooses $k_i = k$, his expected utility is given by

$$\begin{aligned}U_i(x_i, k) &= \mathbf{1}_{x_i<k} \int_{x_i-\sigma}^{x_i+\sigma} \frac{t}{1-l}\frac{1}{2\sigma}\,\mathrm{d}q - t - \xi(k-y)^2 \\ &= \mathbf{1}_{x_i<k}\left(\int_{\min(k-2\sigma,x_i-\sigma)}^{k-\sigma} \frac{t}{2\sigma}\,\mathrm{d}q + \int_{k-\sigma}^{x_i+\sigma} \frac{t}{1-l}\frac{1}{2\sigma}\,\mathrm{d}q\right) - t - \xi(k-y)^2 \\ &= \mathbf{1}_{x_i<k}\left(\int_{\min(k-2\sigma,x_i-\sigma)}^{k-\sigma} \frac{t}{2\sigma}\,\mathrm{d}q + \int_{k-\sigma}^{x_i+\sigma} \frac{t}{k+\sigma-q}\,\mathrm{d}q\right) - t - \xi(k-y)^2 \\ &= \mathbf{1}_{x_i<k} t\left(\frac{k-x_i}{2\sigma} + \ln(2\sigma) - \ln(k-x_i)\right) - t - \xi(k-y)^2, \\ &= t\left(\frac{k-x_i}{2\sigma} + \ln(2\sigma) - \ln(k-x_i)\right) - t - \xi(k-y)^2,\end{aligned}$$

where the second step follows from $l = 0$ if $q < k - \sigma$, the third step follows from substituting in Equation (A.17), and the last step follows from $x_i < k - \sigma < k$. If he chooses $k_i = y$, his expected utility is given by

$$\begin{aligned}U_i(x_i, y) &= \mathbf{1}_{x_i<y} \int_{x_i-\sigma}^{x_i+\sigma} \frac{t}{1-l}\frac{1}{2\sigma}\,\mathrm{d}q - t \\ &= \mathbf{1}_{x_i<y}\left(\int_{\min(k-2\sigma,x_i-\sigma)}^{k-\sigma} \frac{t}{2\sigma}\,\mathrm{d}q + \int_{k-\sigma}^{x_i+\sigma} \frac{t}{1-l}\frac{1}{2\sigma}\,\mathrm{d}q\right) - t \\ &= \mathbf{1}_{x_i<y}\left(\int_{\min(k-2\sigma,x_i-\sigma)}^{k-\sigma} \frac{t}{2\sigma}\,\mathrm{d}q + \int_{k-\sigma}^{x_i+\sigma} \frac{t}{k+\sigma-q}\,\mathrm{d}q\right) - t \\ &= \mathbf{1}_{x_i<y} t\left(\frac{k-x_i}{2\sigma} + \ln(2\sigma) - \ln(k-x_i)\right) - t,\end{aligned}$$

where the second step follows from $l = 0$ if $q < k - \sigma$, the third step follows from substituting in Equation (A.17), and the last step follows from $x_i < k - \sigma < k$. There are two cases to examine: (a) $x_i < y$ and (b) $x_i \geq y$. (a) If $x_i < y$, it is easy to see that $U_i(x_i, y) > U_i(x_i, k)$ and voter $i$ chooses $k_i = y$. (b) If $x_i \geq y$, the gain of following the switching strategy $y$ is given by

$$\begin{aligned}
U_i(x_i, y) - U_i(x_i, k) &= -t - t\left(\frac{k - x_i}{2\sigma} + \ln(2\sigma) - \ln(k - x_i)\right) + t + \xi(k - y)^2 \\
&\geq -t\left(\frac{1}{2} + \ln(2)\right) + \xi(k - y)^2 \\
&> -t\left(\frac{1}{2} + \ln(2)\right) + \xi\sigma^2 \\
&> 0,
\end{aligned}$$

where the second step follows from the expression $\frac{k-x_i}{2\sigma} + \ln(2\sigma) - \ln(k - x_i)$ being the largest at $x_i = k-\sigma$ since $\frac{\partial}{\partial x_i}\left(\frac{k-x_i}{2\sigma} + \ln(2\sigma) - \ln(k - x_i)\right) = -\frac{1}{2\sigma} + \frac{1}{k-x_i} \geq 0$, the third step follows from $y \leq x_i < k - \sigma$, and the last step follows from $\sigma > \sqrt{\frac{t(\frac{1}{2}+\ln(2))}{\xi}}$. Thus, $U_i(x_i, y) > U_i(x_i, k)$ and voter $i$ chooses $k_i = y$. Hence, for $k - 2\sigma \leq x_i < k - \sigma$, the voters follow a switching strategy around $y$.

(iii) If $k - \sigma \leq x_i < k$, for an arbitrary voter $i$, if he chooses $k_i = k$, his utility is given by

$$\begin{aligned}
U_i(x_i, k, l) =&\mathbf{1}_{x_i<k}\left(\int_{x_i-\sigma}^{k} \frac{t}{1 - l}\frac{1}{2\sigma}\,\mathrm{d}q\right) - t - \xi(k - y)^2 \\
=&\mathbf{1}_{x_i<k}\left(\int_{x_i-\sigma}^{k-\sigma} \frac{t}{2\sigma}\,\mathrm{d}q + \int_{k-\sigma}^{k} \frac{t}{1 - l}\frac{1}{2\sigma}\,\mathrm{d}q\right) - t - \xi(k - y)^2 \\
=&\mathbf{1}_{x_i<k}\left(\int_{x_i-\sigma}^{k-\sigma} \frac{t}{2\sigma}\,\mathrm{d}q + \int_{k-\sigma}^{k} \frac{t}{k + \sigma - q}\,\mathrm{d}q\right) - t - \xi(k - y)^2 \\
=&\mathbf{1}_{x_i<k}t\left(\frac{k - x_i}{\sigma} + \ln(2)\right) - t - \xi(k - y)^2 \\
=&t\left(\frac{k - x_i}{\sigma} + \ln(2)\right) - t - \xi(k - y)^2,
\end{aligned} \tag{A.18}$$

where the second step follows from $l = 0$ if $q < k - \sigma$, the third step follows from substituting in Equation (A.17), and the last step follows from $x_i < k$. If he chooses $k_i = y$, his utility is given by

$$
\begin{aligned}
U_i(x_i, y) =& \mathbf{1}_{x_i \geq y}\left(\int_k^{x_i+\sigma} \frac{t}{l}\frac{1}{2\sigma}\,\mathrm{d}q\right) + \mathbf{1}_{x_i<y}\left(\int_{x_i-\sigma}^{k} \frac{t}{1-l}\frac{1}{2\sigma}\,\mathrm{d}q\right) - t \\
=& \mathbf{1}_{x_i \geq y}\left(\int_k^{x_i+\sigma} \frac{t}{l}\frac{1}{2\sigma}\,\mathrm{d}q\right) + \mathbf{1}_{x_i<y}\left(\int_{x_i-\sigma}^{k-\sigma} \frac{t}{2\sigma}\,\mathrm{d}q + \int_{k-\sigma}^{k} \frac{t}{1-l}\frac{1}{2\sigma}\,\mathrm{d}q\right) - t \\
=& \mathbf{1}_{x_i \geq y}\left(\int_k^{x_i+\sigma} \frac{t}{q-k+\sigma}\,\mathrm{d}q\right) + \mathbf{1}_{x_i<y}\left(\int_{x_i-\sigma}^{k-\sigma} \frac{t}{2\sigma}\,\mathrm{d}q + \int_{k-\sigma}^{k} \frac{t}{k+\sigma-q}\,\mathrm{d}q\right) \\
=& \mathbf{1}_{x_i \geq y} t\left(\ln(x_i - k + 2\sigma) - \ln(\sigma)\right) + \mathbf{1}_{x_i<y} t\left(\frac{k-x_i}{\sigma} + \ln(2)\right) - t \\
=& \begin{cases} t\left(\ln(x_i - k + 2\sigma) - \ln(\sigma)\right) - t & \text{if } x_i \geq y, \\ t\left(\frac{k-x_i}{\sigma} + \ln(2)\right) - t & \text{if } x_i < y, \end{cases}
\end{aligned}
\tag{A.19}
$$

where the second step follows from $l = 0$ if $q < k - \sigma$, the third step follows from substituting in Equation (A.17), and the last step follows from re-arranging the terms. There are three cases to examine: (a) $x_i < y$ (b) $x_i \geq y$ and $y < k - \sigma$, and (c) $x_i \geq y$ and $y \geq k - \sigma$.

(a) If $x_i < y$, it is easy to see that $U_i(x_i, y) - U_i(x_i, k) = \xi(k - y)^2 > 0$ and voter $i$ always chooses $k_i = y$.

(b) If $x_i \geq y$ and $y < k - \sigma$, the gain of following the switching strategy $y$ is given by

$$
\begin{aligned}
U_i(x_i, y) - U_i(x_i, k) &= t\left(\ln(x_i - k + 2\sigma) - \ln(\sigma)\right) - t - t\left(\frac{k-x_i}{\sigma} + \ln(2)\right) + t + \xi(k-y)^2 \\
&= -t\left(\frac{k-x_i}{2\sigma} + \ln(2\sigma) - \ln(x_i - k + 2\sigma)\right) + \xi(k-y)^2 \\
&\geq -t\left(\frac{1}{2} + \ln(2)\right) + \xi(k-y)^2 \\
&> -t\left(\frac{1}{2} + \ln(2)\right) + \xi\sigma^2 \\
&> 0,
\end{aligned}
$$

where the third step follows from the expression $\frac{k-x_i}{2\sigma} + \ln(2\sigma) - \ln(x_i - k + 2\sigma)$ being the largest at $x_i = k - \sigma$ since $\frac{\partial}{\partial x_i}\left(\frac{k-x_i}{2\sigma} + \ln(2\sigma) - \ln(x_i - k + 2\sigma)\right) = -\frac{1}{2\sigma} -$

$\frac{1}{x_i-k+2\sigma} < 0$, the fourth step follows from $y < k - \sigma$, and the last step follows from $\sigma > \sqrt{\frac{t(\frac{1}{2}+\ln(2))}{\xi}}$. Thus, $U_i(x_i, y) > U_i(x_i, k)$ and voter $i$ chooses $k_i = y$ if $y < k - \sigma$.

(c) If $x_i \geq y$ and $y \geq k - \sigma$, note that $k > y$ since $y \leq x_i < k$. We show that voter $i$ will always believe that other voters will choose the switching strategy around $y$, hence he will also choose the switching strategy $y$ and vote for the freelancer. To this end, we prove by induction that a voter will always choose the switching strategy around $y$ if he receives a signal $x_i = k^{(n)}$, where $k^{(n)} = k - n\Delta$ for any arbitrarily small $\Delta > 0$. Essentially, $k^{(n)}$ is defined inductively to be the threshold such that at the $n$th round, a voter will vote for the freelancer if he receives a signal $x_i \geq k^{(n)}$. Let $\ell(k^{(n)})$ be the proportion of voters that vote for the freelancer at the start of $n$th round, and is given by Equation (A.17) with $k$ being replaced by $k^{(n)}$. We first prove that the statement is true for $n = 0$. In the first iteration, when $n = 0$, $k^{(0)} = k$ and the proportion of voters that vote for the freelancer is given by $\ell(k^{(0)})$. In this case, for any voter $i$ that receives a signal $x_i = k^{(0)}$, his gain of following the switching strategy $y$ is given by

$$\begin{aligned}
&U_i(k^{(0)}, y) - U_i(k^{(0)}, k) \\
=&t\left(\ln(k^{(0)} - k^{(0)} + 2\sigma) - \ln(\sigma)\right) - t - t\left(\frac{k^{(0)} - k^{(0)}}{2\sigma} + \ln(2)\right) + t + \xi(k - y)^2 \\
=&t\ln(2) - t\ln(2) + \xi(k - y)^2, \\
=&\xi(k - y)^2 \\
>&0,
\end{aligned}$$

where the first step follows from $U_i(k^{(0)}, y)$ as given by Equation (A.19) and $U_i(k^{(0)}, k)$ as given by Equation (A.18) with $x_i = k^{(0)}$ from the current iteration and $l = \ell(k^{(0)})$ from the initial iteration, and the last step follows from $k > y$. Thus, the voters will choose to vote for the freelancer by following the switching strategy $y$ if they receive a signal $x_i = k^{(0)} = k$. Hence, only voters that receive a signal $x_i \leq k^{(1)} = k - \Delta$ do not follow the switching strategy $y$ and will vote for the client. The proportion of voters that vote for the freelancer increases from $\ell(k^{(0)})$ to $\ell(k^{(1)})$. Suppose in the $n$th iteration, it is true that a voter will always choose the switching strategy around $y$ if he receives a signal $x_i = k^{(n)} = k - n\Delta$. Hence, only voters that receive a signal $x_i \leq k^{(n+1)} = k - (n+1)\Delta$ do not follow the switching strategy $y$ and will vote for the client. Consequently, the proportion of voters that vote for the freelancer is given by $\ell(k^{(n+1)})$. We show that it is also true that a voter will always choose the switching strategy around $y$ if he receives a signal $x_i = k^{(n+1)} = k - (n+1)\Delta$. For any voter $i$ who receives a signal $x_i = k^{(n+1)} = k-(n+1)\Delta$, his gain of following the switching strategy $y$ is given by

$$
\begin{aligned}
&U_i(k^{(n+1)}, y) - U_i(k^{(n+1)}, k) \\
=&t\left(\ln(k^{(n+1)} - k^{(n+1)} + 2\sigma) - \ln(\sigma)\right) - t - t\left(\frac{k^{(n+1)} - k^{(n+1)}}{2\sigma} + \ln(2)\right) + t + \xi(k-y)^2 \\
=&t\ln(2) - t\ln(2) + \xi(k-y)^2, \\
=&\xi(k-y)^2 \\
>&0,
\end{aligned}
$$

where the first step follows from $U_i(k^{(n+1)}, y)$ as given by Equation (A.19) and $U_i(k^{(n+1)}, k)$ as given by Equation (A.18) with $x_i = k^{(n+1)}$ from the current iteration and $l = \ell(k^{(n+1)})$ from the previous iteration, and the last step follows from $k > y$. Thus, the voters will choose the switching strategy $y$ and vote for the freelancer if they receive a signal $x_i = k^{(n+1)}$. Hence, only voters that receive a signal $x_i \leq k^{(n+2)} = k - (n+2)\Delta$ do not follow the switching strategy $y$ and will vote for the client. The proportion of voters that vote for the freelancer increases from $\ell(k^{(n+1)})$ to $\ell(k^{(n+2)})$. Therefore, as $n \to \infty$, $k^{(n)} \to y$ and all the voters follow the switching strategy around $y$.

Following a similar approach, we can show that the voters follow the switching strategy around $y$ for $x_i \geq k$. Thus, if $\sigma > \sqrt{\frac{t(\frac{1}{2}+\ln(2))}{\xi}}$, the switching strategy around $y$ is the unique threshold equilibrium. □

*Proof of Proposition 1.3* Proposition 1.3 can be proven by backward induction based on the decision tree in Figure 1.1.

The analysis for Stages 2 to 6 to obtain $q^+$ and $p^+$ follows from the proof of Proposition 1.1 with $h^*(q)$ being replaced by $h^+(q)$ since the utilities of the freelancer and the client are similar. Thus, there exists a threshold $\underline{\alpha}_d$ such that dispute does not occur if $\alpha \leq \underline{\alpha}_d$ and dispute occurs if $\alpha > \underline{\alpha}_d$. $q^+$ is then given by

$$q^+ = \begin{cases} y + \sigma & \text{if } \alpha \leq \underline{\alpha}_d, \\ \frac{(1-\gamma)p}{4\sigma\alpha} & \text{if } \alpha > \underline{\alpha}_d, \end{cases} \tag{A.20}$$

and $p^+ = \max(\frac{\alpha(y+\sigma)^2}{1-\gamma}, \frac{f}{1-\gamma})$ if $\alpha \leq \underline{\alpha}_d$, and

$$p^+ = \begin{cases} \hat{p}_d & \text{if } f \leq \underline{f}_d, \\ \frac{\underline{f}_d+\alpha(q^+)^2}{h^+(q^+)(1-\gamma)} & \text{if } f > \underline{f}_d, \end{cases} \tag{A.21}$$

where $\hat{p}_d$ is the solution to the unconstrained client's problem, and $\underline{f}_d$ is the threshold such that $\hat{p}_d = \frac{\underline{f}_d+\alpha(q^+)^2}{h^+(q^+)(1-\gamma)}$.

At Stage 1, the platform chooses the dispute fee $f$ while satisfying the individual rationality constraints of the client and the freelancer.

(a) Recall from previous analyses that if $\alpha \leq \underline{\alpha}_d$, dispute does not occur. The freelancer chooses quality $q^+ = y + \sigma$ and the client offers price $p^+ = \max(\frac{\alpha(y+\sigma)^2}{1-\gamma}, \frac{f}{1-\gamma})$. Thus, the platform will achieve a utility of $\Pi(f) = \gamma p^+ = \gamma \max(\frac{\alpha(y+\sigma)^2}{1-\gamma}, \frac{f}{1-\gamma})$. Based on Equation (1.6), the platform's optimization problem is as follows:

$$
\begin{aligned}
\max_{f \geq 0} \quad & \gamma \max\left(\frac{\alpha(y+\sigma)^2}{1-\gamma}, \frac{f}{1-\gamma}\right), \\
\text{s.t.} \quad & (y+\sigma) - \max\left(\frac{\alpha(y+\sigma)^2}{1-\gamma}, \frac{f}{1-\gamma}\right) \geq 0, && \text{(A.22)} \\
& -\alpha\,(y+\sigma)^2 + (1-\gamma)\max\left(\frac{\alpha(y+\sigma)^2}{1-\gamma}, \frac{f}{1-\gamma}\right) \geq 0, && \text{(A.23)}
\end{aligned}
$$

where Equation (A.22) is the individual rationality constraint of the client, and Equation (A.23) is the individual rationality constraint of the freelancer.

Notice from the above problem formulation that the case of $\frac{f}{1-\gamma} \leq \frac{\alpha(y+\sigma)^2}{1-\gamma}$ is equivalent to $\frac{f}{1-\gamma} = \frac{\alpha(y+\sigma)^2}{1-\gamma}$. We thus focus on $\frac{f}{1-\gamma} \geq \frac{\alpha(y+\sigma)^2}{1-\gamma}$, or equivalently, $f \geq \alpha(y+\sigma)^2$. In this case, the platform's utility reduces to $\Pi = \frac{\gamma f}{1-\gamma}$, Equation (A.22) reduces to $f \leq (1-\gamma)(y+\sigma)$, and Equation (A.23) reduces to $f \geq \alpha(y+\sigma)^2$. Thus, if $\alpha(y+\sigma)^2 > (1-\gamma)(y+\sigma)$, or equivalently, $y+\sigma > \frac{1-\gamma}{\alpha}$, the problem is infeasible. If $y+\sigma \leq \frac{1-\gamma}{\alpha}$, since $\Pi$ is increasing in $f$, we have

$$
f^{+} = (1-\gamma)(y+\sigma), \tag{A.24}
$$

which also satisfies $f^{+} \geq \alpha(y+\sigma)^2$. Since $p^{+} = \frac{f}{1-\gamma}$, from Equation (A.24) we have $p^{+} = y+\sigma = q^{+}$. Hence, the platform's equilibrium utility is $\Pi^{+} = \gamma(y+\sigma)$. Consequently, following the proof of Proposition 1.1, $\underline{\alpha}_d = \frac{1-\gamma}{y+\sigma}$.

(b) Recall from previous analyses that if $\alpha > \underline{\alpha}_d$, dispute occurs. The freelancer chooses quality $q^{+} = \frac{(1-\gamma)p^{+}}{4\sigma\alpha}$ and the client offers price $p^{+}$ based on Equation (A.21). Based on Equation (1.6), the platform's optimization problem is as follows:

$$
\begin{aligned}
\max_{f \geq 0} \quad & h^{+}(q^{+})\gamma p^{+} + f, \\
\text{s.t.} \quad & q^{+} - h^{+}(q^{+})p^{+} \geq 0, && \text{(A.25)} \\
& -\alpha(q^{+})^2 + h^{+}(q^{+})(1-\gamma)p^{+} - f \geq 0, && \text{(A.26)}
\end{aligned}
$$

where Equation (A.25) is the individual rationality constraint of the client and Equation (A.26) is the individual rationality constraint of the freelancer.

We next optimize the platform's decision on $f$. Recall from Stage 2(b) that if $\underline{f}_d \leq (1-\gamma)(q^+)-\alpha(q^+)^2$, $U_c \geq 0$. Since $\frac{\partial U_c}{\partial f}\big|_{p=\bar{p}_d} = \frac{\partial U_c}{\partial p}\big|_{p=\bar{p}_d}\frac{\partial \bar{p}_d}{\partial f} < 0$, $U_c$ is decreasing in $f$. Thus, there exists a threshold $\bar{f}_d$, where $\bar{f}_d > \underline{f}_d$, such that $U_c \geq 0$ if and only if $f \leq \bar{f}_d$. Moreover, we have shown previously that $U_c = 0$ if $f = (1-\gamma)(q^+)-\alpha(q^+)^2$, and thus, $\bar{f}_d = (1-\gamma)q^+ - \alpha(q^+)^2$. Therefore, there are three possible cases of $f$, which are defined as follows:

Case b.1: $f \leq \underline{f}_d < \bar{f}_d \Rightarrow U_f \geq 0$ and $U_c \geq 0$,

Case b.2: $\underline{f}_d < f \leq \bar{f}_d \Rightarrow U_f = 0$ and $U_c \geq 0$,

Case b.3: $f > \bar{f}_d \Rightarrow$ No contracting occurs.

Under Case b.1, since $f \leq \underline{f}_d$, $p^+ = \hat{p}_d$ and $q^+$ are both constant in $f$. This implies that the platform's utility $\Pi$ is increasing in $f$. As such, $f^+ = \underline{f}_d$, under which $U_f = 0$ and $U_c > 0$. Under Case b.2, since $f > \underline{f}_d$ and $f \leq \bar{f}_d$, $p^+ = \bar{p}_d$ and $q^+$ both depend on $f$. Thus, the derivative of $\Pi$ with respect to $f$ is given by

$$\begin{aligned}\frac{\partial \Pi}{\partial f} &= \gamma\left[\frac{\partial h^+(q^+)}{\partial f}\bar{p}_d + h^+(q^+)\frac{\partial \bar{p}_d}{\partial f}\right] + 1\\ &= \gamma\left[\frac{\partial h^+(q^+)}{\partial q^+}\frac{\partial q^+}{\partial p}\Big|_{p=\bar{p}_d}\bar{p}_d + h^+(q^+)\right]\frac{\partial \bar{p}_d}{\partial f} + 1\\ &> 0,\end{aligned}$$

where the second step follows from applying the chain rule to $\frac{\partial q^+}{\partial f}$, and the last step follows from $\frac{\partial q^+}{\partial p} > 0$ and $\frac{\partial \bar{p}_d}{\partial f} > 0$. Since $\Pi$ is increasing in $f$ throughout Case b.1 and Case b.2, $U_c^+ = 0$ and $U_f^+ = 0$. Consequently, the optimal dispute fee is

$$f^+ = (1-\gamma)(q^+) - \alpha(q^+)^2, \tag{A.27}$$

and from the binding individual rationality constraint of the client in Equation (A.25), we obtain the client's equilibrium the offer price is $p^+ = \frac{q^+}{h^+(q^+)}$. From

Equation (A.20), we obtain $q^+ = \frac{(1-\gamma)p^+}{4\alpha\sigma}$. Substituting $q^+$ into Equation (A.25), we have

$$\begin{aligned} & q^+ - h^+(q^+)p^+ = 0 \\ \Leftrightarrow\ & q^+ - \left(\frac{q^+ - y + \sigma}{2\sigma}\right)p^+ = 0 \\ \Leftrightarrow\ & \frac{(1-\gamma)p^+}{4\alpha\sigma} - \left(\frac{\frac{(1-\gamma)p^+}{4\alpha\sigma} - y + \sigma}{2\sigma}\right)p^+ = 0 \\ \Leftrightarrow\ & p^+ = \frac{2\sigma(2\alpha(y-\sigma) + (1-\gamma))}{1-\gamma}, \end{aligned}$$

where the first step follows from $h^+(q^+) = \frac{q^+ - y + \sigma}{2\sigma}$ and the second step follows from $q^+ = \frac{(1-\gamma)p^+}{4\alpha\sigma}$. Therefore, from Equation (A.20), we have

$$q^+ = \frac{1-\gamma}{2\alpha} + y - \sigma,$$

and from Equation (A.27), we have

$$f^+ = \frac{(2\alpha(y-\sigma) + (1-\gamma))(-2\alpha(y-\sigma) + (1-\gamma))}{4\alpha}.$$

Therefore, the platform's utility is

$$\begin{aligned} \Pi^+ &= h^+(q^+)\gamma p^+ + f^+ \\ &= \frac{(2\alpha(y-\sigma) + (1-\gamma))(-2\alpha(y-\sigma) + (1+\gamma))}{4\alpha}. \end{aligned}$$

Moreover, since $f^+ \geq 0$ for contracting to occur, if $\sigma > y$, $f^+ = 0$ at $\alpha = \frac{1-\gamma}{2(\sigma-y)}$. If $\sigma \leq y$, $f^+ = 0$ at $\alpha = \frac{1-\gamma}{2(y-\sigma)}$. Therefore, if dispute occurs, there exists a threshold $\hat{\alpha}_d$, which is the solution of $f^+ = q^+((1-\gamma) - \hat{\alpha}_d q^+) = 0$, such that $f^+ \geq 0$ if and only if $\alpha \leq \hat{\alpha}_d$, where $\hat{\alpha}_d$ is given by

$$\hat{\alpha}_d = \begin{cases} \frac{1-\gamma}{2(y-\sigma)} & \text{if } \sigma \leq y, \\ \frac{1-\gamma}{2(\sigma-y)} & \text{if } \sigma > y. \end{cases}$$

If $\alpha > \hat{\alpha}_d$, since the dispute fee has to be non-negative, setting $f^+ = 0$ would cause the individual rationality constraint of the freelancer to be violated. We define $\bar{\alpha}_d = \max(\underline{\alpha}_d, \hat{\alpha}_d)$. Contracting occurs in equilibrium if and only if $\alpha \leq \bar{\alpha}_d$. Thus, given that contracting occurs, dispute occurs in equilibrium if and only if $\underline{\alpha}_d < \alpha \leq \bar{\alpha}_d$. □

## A.4 Proofs of Section 1.6 (Value of Decentralization)

*Proof of Theorem 1.1* We first compare the $\alpha$ thresholds below which dispute does not occur between the centralized and decentralized dispute systems. Under the centralized dispute system, $\underline{\alpha}_c = \frac{(1-\gamma)(\gamma+4\sigma\theta)}{4\sigma\theta(y+\sigma)}$; under the decentralized dispute system, $\underline{\alpha}_d = \frac{1-\gamma}{y+\sigma}$. Thus, the difference between $\underline{\alpha}_d$ and $\underline{\alpha}_c$ is $\underline{\alpha}_d - \underline{\alpha}_c = -\frac{\gamma(1-\gamma)}{4\sigma\theta(y+\sigma)} \leq 0$ and hence, $\underline{\alpha}_d \leq \underline{\alpha}_c$.

We next compare the $\alpha$ thresholds beyond which contracting does not occur between the centralized and decentralized dispute systems. If $\sigma > y$, under the centralized dispute system, $\bar{\alpha}_c = \max(\underline{\alpha}_c, \frac{1-\gamma}{2(\sigma-y)})$; under the decentralized dispute system, $\bar{\alpha}_d = \max(\underline{\alpha}_d, \frac{1-\gamma}{2(\sigma-y)})$. In this case, it is easy to see that $\bar{\alpha}_d \leq \bar{\alpha}_c$ since $\underline{\alpha}_d \leq \underline{\alpha}_c$. If $\sigma \leq y$, under the centralized dispute system, $\bar{\alpha}_c = \max(\underline{\alpha}_c, \frac{(1-\gamma)\theta}{2(\theta(y-\sigma)-\gamma)})$ if $\sigma \leq y - \frac{\gamma}{\theta}$ and $\bar{\alpha}_c \to \infty$ if $y - \frac{\gamma}{\theta} < \sigma \leq y$; under the decentralized dispute system, $\bar{\alpha}_d = \max(\underline{\alpha}_d, \frac{1-\gamma}{2(y-\sigma)})$. If $y - \frac{\gamma}{\theta} < \sigma \leq y$, we can obtain $f^* \geq 0$ for all $\alpha$ under the centralized dispute system from Equation (A.12), and thus, $\bar{\alpha}_c \geq \bar{\alpha}_d$. If $\sigma \leq y - \frac{\gamma}{\theta}$, as we know from the above that $\underline{\alpha}_d \leq \underline{\alpha}_c$, we now compare the case where $\bar{\alpha}_d = \frac{1-\gamma}{2(y-\sigma)}$ with $\bar{\alpha}_c = \frac{(1-\gamma)\theta}{2(\theta(y-\sigma)-\gamma)}$. We obtain $\bar{\alpha}_d - \bar{\alpha}_c = \frac{1-\gamma}{2(y-\sigma)} - \frac{(1-\gamma)\theta}{2(\theta(y-\sigma)-\gamma)} = \frac{-(1-\gamma)\gamma}{2(y-\sigma)(\theta(y-\sigma)-\gamma)} \leq 0$. Therefore, we have $\bar{\alpha}_d \leq \bar{\alpha}_c$. □

*Proof of Theorem 1.2* We compare the equilibrium quality levels, contract prices and dispute fees between the centralized and decentralized dispute systems, such that contracting occurs under both the centralized and decentralized dispute systems. We first analyze the case where dispute does not occur under either system (i.e., $\alpha \leq \underline{\alpha}_d$). We then analyze the case where dispute occurs under the decentralized dispute system but does not occur under the centralized dispute system (i.e., $\underline{\alpha}_d < \alpha \leq \underline{\alpha}_c$). Finally, we analyze the case where dispute occurs under both systems (i.e., $\alpha > \underline{\alpha}_c$).

(a) If $\alpha \leq \underline{\alpha}_d$, under the centralized dispute system, $q^* = \frac{4\sigma\theta(y+\sigma)}{\gamma+4\sigma\theta}$; under the decentralized dispute system, $q^+ = y + \sigma$. Therefore, $q^+ - q^* = \frac{\gamma(y+\sigma)}{\gamma+4\theta\sigma} > 0$. Moreover, as $p^* = q^*$ and $p^+ = q^+$, we have $p^* > p^+$. And as $f^* = (1-\gamma)p^*$ and $f^+ = (1-\gamma)p^+$, we have $f^+ > f^*$.

(b) If $\underline{\alpha}_d < \alpha \leq \underline{\alpha}_c$, we first note the regions for dispute to occur under the decentralized dispute system. Recall that dispute takes place under the decentralized dispute system if $\bar{\alpha}_d > \underline{\alpha}_d$. If $\sigma \leq y$, for $\bar{\alpha}_d - \underline{\alpha}_d = \frac{(1-\gamma)(3\sigma-y)}{2(y+\sigma)(y-\sigma)} > 0$, we require $\frac{y}{3} < \sigma$. Therefore, $\frac{y}{3} < \sigma \leq y$ for dispute to occur under the decentralized dispute system. If $\sigma > y$, for $\bar{\alpha}_d - \underline{\alpha}_d = \frac{(1-\gamma)(3y-\sigma)}{2(y+\sigma)(\sigma-y)} > 0$, we require $\sigma < 3y$. Therefore, $\frac{y}{3} < \sigma \leq 3y$ for dispute to occur under the decentralized dispute system.

For the quality level, under the centralized dispute system, $q^* = \frac{4\sigma\theta(y+\sigma)}{\gamma+4\sigma\theta}$; under the decentralized dispute system, $q^+ = \frac{1-\gamma}{2\alpha} + y - \sigma$. Thus, the difference is given by

$$q^+ - q^* = \frac{1-\gamma}{2\alpha} + y - \sigma - \frac{4\sigma\theta(y+\sigma)}{\gamma + 4\sigma\theta},$$

which is zero if $\alpha = \frac{(1-\gamma)(\gamma+4\sigma\theta)}{2\left(\gamma(\sigma-y)+8\sigma^2\theta\right)}$ and is decreasing in $\alpha$ as $\frac{\partial}{\partial\alpha}(q^+ - q^*) = -\frac{1-\gamma}{2\alpha^2} < 0$. Therefore, since $\frac{\partial}{\partial\alpha}(q^+ - q^*) < 0$, $q^+ - q^*$ is the most negative at $\underline{\alpha}_c$. At $\alpha = \underline{\alpha}_c$, the difference becomes

$$q^+ - q^* = \frac{2\sigma\theta(y-3\sigma) + \gamma(y-\sigma)}{\gamma + 4\sigma\theta},$$

which is positive if $\sigma \leq \frac{\sqrt{(\gamma+2\theta y)^2+16\gamma\theta y} - \gamma + 2\theta y}{12\theta} = \bar{\sigma}$ since the other root of $q^+ - q^* = 0$ is negative, and is negative otherwise. Thus, there exists a threshold $\alpha_q \leq \underline{\alpha}_c$, such that $q^+ \geq q^*$ if $\alpha \leq \alpha_q$ and $q^+ < q^*$ if $\alpha_q < \alpha \leq \underline{\alpha}_c$. Moreover, if $\sigma \leq \bar{\sigma}$, $q^+ \geq q^*$.

For the contract price, under the centralized dispute system, $p^* = \frac{4\sigma\theta(y+\sigma)}{\gamma+4\sigma\theta}$;

under the decentralized dispute system, $p^+ = \frac{2\sigma(2\alpha(y-\sigma)+(1-\gamma))}{1-\gamma}$. Thus, the difference is

$$p^+ - p^* = \frac{2\sigma(2\alpha(y-\sigma)+(1-\gamma))}{1-\gamma} - \frac{4\sigma\theta(y+\sigma)}{\gamma+4\sigma\theta},$$

which is zero if $\alpha = \frac{(1-\gamma)(\gamma+2\theta(\sigma-y))}{2(\gamma+4\sigma\theta)(\sigma-y)}$. Taking the derivative of the difference, we have

$$\frac{\partial}{\partial\alpha}(p^+ - p^*) = \frac{4\sigma(y-\sigma)}{1-\gamma},$$

which is increasing in $\alpha$ if $\sigma \le y$ and decreasing in $\alpha$ if $\sigma > y$. If $\sigma \le y$, $p^+ - p^*$ is the most negative at $\underline{\alpha}_d$. At $\alpha = \underline{\alpha}_d$, the difference becomes

$$\begin{aligned} p^+ - p^* &= \frac{4\sigma(\gamma+3\sigma\theta-\theta y)}{\gamma+4\sigma\theta} \\ &> 0, \end{aligned}$$

where the last step follows from $\frac{y}{3} < \sigma \le y$ for dispute to occur under the decentralized dispute system. If $\sigma > y$, $p^+ - p^*$ is the most negative at $\underline{\alpha}_c$. At $\alpha = \underline{\alpha}_c$, the difference becomes

$$p^+ - p^* = \frac{\left(\gamma^2(y-\sigma) + 2\gamma\sigma\theta(5y-3\sigma) - 4\sigma\theta^2\left(3\sigma^2 - 4\sigma y + y^2\right)\right)}{\theta(\sigma+y)(\gamma+4\sigma\theta)},$$

which can be negative if $\theta \le \frac{-\sqrt{-\gamma^2\sigma(3\sigma-4y)(\sigma+y)^2}+\gamma\sigma(5y-3\sigma)}{4\sigma\left(3\sigma^2-4\sigma y+y^2\right)}$ or $\theta \ge \frac{\sqrt{-\gamma^2\sigma(3\sigma-4y)(\sigma+y)^2}+\gamma\sigma(5y-3\sigma)}{4\sigma\left(3\sigma^2-4\sigma y+y^2\right)}$. Thus, there exists a threshold $\alpha_p$, such that $p^+ \ge p^*$ if $\alpha \le \alpha_p$ and $p^+ < p^*$ if $\alpha_p < \alpha \le \underline{\alpha}_c$. Moreover, if $\sigma \le \bar{\sigma}$, $p^+ = \frac{q^+}{h^+(q^+)} \ge q^* = p^*$.

Finally, we note that if $\sigma \le \bar{\sigma}$, $\bar{\alpha}_d \le \underline{\alpha}_c$ as the difference $\underline{\alpha}_c - \bar{\alpha}_d$ is given by

$$\frac{(1-\gamma)(\gamma+4\sigma\theta)}{4\sigma\theta(y+\sigma)} - \frac{1-\gamma}{2(y-\sigma)} = \frac{1-\gamma}{4}\left(\frac{\gamma(\sigma-y)+2\sigma\theta(3\sigma-y)}{\sigma\theta(y-\sigma)(y+\sigma)}\right),$$

which is positive if $\sigma \le \bar{\sigma}$. Therefore, given that $\sigma \le \bar{\sigma}$, $q^+ \ge q^*$ and $p^+ \ge p^*$ if $\alpha \le \bar{\alpha}_d$.

(c) If $\alpha > \underline{\alpha}_c$ such that dispute can occur under both systems (i.e., $\bar{\alpha}_d > \underline{\alpha}_c$), for the quality level, under the centralized dispute system, $q^* = \frac{(1-\gamma)\theta(2\alpha(y-\sigma)+(1-\gamma))}{2\alpha(\gamma\alpha+(1-\gamma)\theta)}$; under the decentralized dispute system, $q^+ = \frac{1-\gamma}{2\alpha} + y - \sigma$. Thus, the difference is given by

$$
\begin{aligned}
q^+ - q^* &= \frac{1-\gamma}{2\alpha} + y - \sigma - \frac{(1-\gamma)\theta(2\alpha(y-\sigma)+(1-\gamma))}{2\alpha\,(\gamma\alpha+(1-\gamma)\theta)} \\
&= \frac{\gamma(2\alpha(y-\sigma)+(1-\gamma))}{2(\gamma\alpha-\gamma\theta+\alpha)} \\
&> 0,
\end{aligned}
$$

where the second step follows from re-arranging the terms and the last step follows from $\alpha \leq \bar{\alpha}_d$.

For the contract price, under the centralized dispute system, $p^* = \frac{2\sigma\theta(2\alpha(y-\sigma)+(1-\gamma))}{\gamma\alpha+(1-\gamma)\theta}$; under the decentralized dispute system, $p^+ = \frac{2\sigma(2\alpha(y-\sigma)+(1-\gamma))}{1-\gamma}$. Thus, the difference is given by

$$
\begin{aligned}
p^+ - p^* &= \frac{2\sigma(2\alpha(y-\sigma)+(1-\gamma))}{1-\gamma} - \frac{2\sigma\theta(2\alpha(y-\sigma)+(1-\gamma))}{\gamma\alpha+(1-\gamma)\theta} \\
&= \frac{2\gamma\alpha\sigma(2\alpha(y-\sigma)+(1-\gamma))}{(1-\gamma)(\gamma\alpha+(1-\gamma)\theta)} \\
&> 0,
\end{aligned}
$$

where the second step follows from re-arranging the terms and the last step follows from $\alpha \leq \bar{\alpha}_d$.

For the dispute fee, under the centralized dispute system, $f^* = \frac{(1-\gamma)^2\theta(2\alpha(y-\sigma)+(1-\gamma))((1-\gamma)\theta+2\alpha(\gamma-\theta(y-\sigma)))}{4\alpha(\gamma\alpha+(1-\gamma)\theta)^2}$; under the decentralized dispute system, $f^+ = \frac{(2\alpha(y-\sigma)+(1-\gamma))(-2\alpha(y-\sigma)+(1-\gamma))}{4\alpha}$. Thus, the difference is given by

$$
f^+ - f^* = \frac{\gamma\alpha(2\alpha(y-\sigma)+(1-\gamma))\left(\gamma(2(\alpha-2\theta)(\sigma-y)+1)-\gamma^2-4\theta(y-\sigma)\right)}{4(\gamma\alpha+(1-\gamma)\theta)^2},
$$

which is positive if

$$
\gamma\alpha(2\alpha(y-\sigma)+(1-\gamma))\left(\gamma(2(\alpha-2\theta)(\sigma-y)+1)-\gamma^2-4\theta(y-\sigma)\right) \geq 0. \tag{A.28}
$$

If $\sigma > y$, then Equation (A.28) is always positive and $f^+ \geq f^*$ if $\alpha \leq \bar{\alpha}_d$. If $\sigma \leq y$, $f^+ \geq f^*$ if $\alpha \leq \frac{(1-\gamma)(\gamma-4\theta(y-\sigma))}{2\gamma(y-\sigma)}$ and $f^+ < f^*$ if $\alpha > \frac{(1-\gamma)(\gamma-4\theta(y-\sigma))}{2\gamma(y-\sigma)}$. Comparing $\alpha = \frac{(1-\gamma)(\gamma-4\theta(y-\sigma))}{2\gamma(y-\sigma)}$ with $\bar{\alpha}_d$, we have

$$\frac{(1-\gamma)(\gamma-4\theta(y-\sigma))}{2\gamma(y-\sigma)} - \frac{1-\gamma}{2(y-\sigma)} = -\frac{2\theta(1-\gamma)}{\gamma} \leq 0.$$

Thus, there exists a threshold, $\alpha_f$, where

$$\alpha_f = \begin{cases} \max(\underline{\alpha}_c, \frac{(1-\gamma)(\gamma-4\theta(y-\sigma))}{2\gamma(y-\sigma)}) & \text{if } \sigma \leq y, \\ \bar{\alpha}_d & \text{if } \sigma > y, \end{cases}$$

such that $f^+ \geq f^*$ if $\alpha \leq \alpha_f$ and $f^+ < f^*$ if $\alpha > \alpha_f$. □

*Proof of Theorem 1.3* We compare the platform's equilibrium utilities between the centralized and decentralized dispute systems.

(a) If $\alpha \leq \underline{\alpha}_d$, dispute does not occur under either system. In this case, under the centralized dispute system, $\Pi^* = \gamma p^*$; under the decentralized dispute system, $\Pi^+ = \gamma p^+$. Therefore, we have $\Pi^+ \geq \Pi^*$ as $p^+ \geq p^*$.

(b) If $\underline{\alpha}_d < \alpha \leq \underline{\alpha}_c$, dispute occurs under the decentralized dispute system but does not occur under the centralized dispute system. In this case, under the centralized dispute system, $\Pi^* = \gamma p^* = \gamma\frac{4\sigma\theta(y+\sigma)}{\gamma+4\sigma\theta}$; under the decentralized dispute system, $\Pi^+ = h^+(q^+)\gamma p^+ + f^+ = \frac{(2\alpha(y-\sigma)+(1-\gamma))(-2\alpha(y-\sigma)+(1+\gamma))}{4\alpha}$. Note that if $\sigma < \frac{y}{3}$, dispute does not occur under the decentralized dispute system and thus, $\Pi^+ \geq \Pi^*$ if $\alpha \leq \underline{\alpha}_d = \bar{\alpha}_d$. Thus, the difference in the platform's utilities under the two different dispute systems is

$$\begin{aligned} &\Pi^+ - \Pi^* \\ =&\frac{4\sigma\theta\left(1-4\alpha^2(y-\sigma)^2\right) - 4\gamma^2(\sigma(\alpha+\theta)-\alpha y) + \gamma\left(1-4\alpha\left(\alpha(y-\sigma)^2+8\sigma^2\theta\right)\right) - \gamma^3}{4\alpha(\gamma+4\sigma\theta)}, \end{aligned} \tag{A.29}$$

which is decreasing with $\alpha$ as $\frac{\partial}{\partial\alpha}(\Pi^+ - \Pi^*) = -\frac{(1-\gamma^2)+4\alpha^2(y-\sigma)^2}{4\alpha^2} < 0$.

However, recall from the proof of Theorem 1.2 that if $\frac{y}{3} \le \sigma \le \bar{\sigma}$, we have $\Pi^+ = h^+(q^+)\gamma p^+ + f^+ = \gamma q^+ + f^+ \ge \gamma q^* = \Pi^*$ since $q^+ \ge q^*$. Moreover, in this case, $\bar{\alpha}_d \le \underline{\alpha}_c$ and we have $\Pi^+ \ge \Pi^*$ if $\alpha \le \bar{\alpha}_d$ and $\Pi^+ < \Pi^*$ otherwise.

If $\bar{\sigma} < \sigma \le y$, $\bar{\alpha}_d \ge \underline{\alpha}_c$. From Equation (A.29), the difference in the platform's utilities at $\alpha = \underline{\alpha}_c$ is

$$\Pi^+ - \Pi^* = \frac{(\gamma(y-\sigma) + 2\sigma\theta(y-3\sigma))\,(2\sigma(\sigma+\gamma\sigma-3y+5\gamma y)\theta - (1-\gamma)\gamma(y-\sigma))}{4\sigma\theta(\sigma+y)(\gamma+4\sigma\theta)}. \tag{A.30}$$

From the proof of Theorem 1.2, $\gamma(y-\sigma)+2\sigma\theta(y-3\sigma) < 0$ if $\sigma > \bar{\sigma}$. Thus, Equation (A.30) is positive if the second term in the numerator is $2\sigma(\sigma+\gamma\sigma-3y+5\gamma y)\theta - (1-\gamma)\gamma(y-\sigma) \le 0$. Thus, we have

$$\begin{aligned}
2\sigma(\sigma+\gamma\sigma-3y+5\gamma y)\theta - (1-\gamma)\gamma(y-\sigma) \le& 2\sigma(\sigma+\gamma\sigma-3y+5\gamma y)\theta \\
\le& 2\sigma(\frac{4}{3}(\sigma-y))\theta \\
\le& 0,
\end{aligned}$$

where the first step follows from $\sigma \le y$, the second step follows from the inequality being largest at $\gamma = \frac{1}{3}$ and the last step follows from $\sigma \le y$. In this case, given that $\bar{\sigma} < \sigma \le y$, we have $\Pi^+ - \Pi^* \ge 0$ if $\underline{\alpha}_d < \alpha \le \underline{\alpha}_c$.

(c) If $\alpha > \underline{\alpha}_c$, dispute occurs under both systems. In this case, under the centralized dispute system,
$\Pi^* = \frac{\theta(2\alpha(y-\sigma)+(1-\gamma))\left(-2\gamma^2\alpha^2(y-\sigma)+(1-\gamma)\alpha((2-\gamma)\gamma-2\gamma\sigma\theta-2(1-\gamma)\theta y+2\sigma\theta)+(1+\gamma)(1-\gamma)^2\theta\right)}{4\alpha(\gamma\alpha+(1-\gamma)\theta)^2}$; under the decentralized dispute system, $\Pi^+ = \frac{(2\alpha(y-\sigma)+(1-\gamma))(-2\alpha(y-\sigma)+(1+\gamma))}{4\alpha}$. Therefore, the difference in the platforms' utilities is given by

$$\begin{aligned}
\Pi^+ - \Pi^* =& \frac{1}{4(\gamma\alpha+(1-\gamma)\theta)^2}\Big[\gamma(2\alpha(y-\sigma)+(1-\gamma))\Big(-2\gamma\alpha^2(y-\sigma) \\
&+ \alpha\left(\gamma^2+\gamma(1-6\sigma\theta+6\theta y)-4\theta(y-\sigma)\right) + 3(1-\gamma)\gamma\theta\Big)\Big].
\end{aligned} \tag{A.31}$$

We first solve for $\Pi^+ - \Pi^* = 0$. Note that the first factor in the numerator of the first term of Equation (A.31), $\gamma(2\alpha(y-\sigma)+(1-\gamma)) \ge$

0, is always positive as $\sigma \leq y$. Thus, the roots of $\Pi^+ - \Pi^* = 0$ are determined by $-2\alpha^2\gamma(y-\sigma) + \alpha\left(\gamma^2 + \gamma(1 - 6\sigma\theta + 6\theta y) - 4\theta(y-\sigma)\right) + 3(1-\gamma)\gamma\theta$, which is quadratic downwards in terms of $\alpha$. The roots are $\alpha = \frac{\pm\sqrt{24(1-\gamma)\gamma^2\theta(y-\sigma)+(\gamma^2+\gamma(1+6\theta(y-\sigma))-4\theta(y-\sigma))^2}+\gamma^2+\gamma(1+6\theta(y-\sigma))-4\theta(y-\sigma)}{4\gamma(y-\sigma)}$. Let $\bar{\bar{\alpha}} = \frac{\sqrt{24(1-\gamma)\gamma^2\theta(y-\sigma)+(\gamma^2+\gamma(1+6\theta(y-\sigma))-4\theta(y-\sigma))^2}+\gamma^2+\gamma(1+6\theta(y-\sigma))-4\theta(y-\sigma)}{4\gamma(y-\sigma)}$. Hence, $\Pi^+ - \Pi^*$ is positive if $\alpha \leq \bar{\bar{\alpha}}$ as the other root of $\Pi^+ - \Pi^* = 0$ is always negative. Moreover, at $\alpha = \bar{\alpha}_d = \frac{1-\gamma}{2(y-\sigma)}$, from Equation (A.31), we obtain

$$\Pi^+ - \Pi^* = \frac{2\gamma(y-\sigma)\left(\gamma^2 + 6\gamma\theta(y-\sigma) - 2\theta(y-\sigma)\right)}{(\gamma + 2\theta(y-\sigma))^2},$$

which is negative if $\sigma \leq y - \frac{\gamma^2}{2(1-3\gamma)\theta}$ and positive if $y - \frac{\gamma^2}{2(1-3\gamma)\theta} < \sigma \leq y$. Hence, $\Pi^+ \geq \Pi^*$ if $\alpha \leq \min(\bar{\alpha}_d, \max(\underline{\alpha}_c, \bar{\bar{\alpha}}))$ and $\Pi^+ < \Pi^*$ otherwise.

Therefore, combining all the cases, we have $\Pi^+ \geq \Pi^*$ if and only if $\alpha \leq \bar{\alpha}$, where

$$\bar{\alpha} = \begin{cases} \bar{\alpha}_d & \text{if } \sigma \leq \bar{\sigma}, \\ \min(\bar{\alpha}_d, \max(\underline{\alpha}_c, \bar{\bar{\alpha}})) & \text{if } \bar{\sigma} < \sigma \leq y. \end{cases}$$

□

*Proof of Theorem 1.4* Given that the socially optimal quality level is $\frac{1}{2\alpha}$, the condition for the equilibrium quality level to be closer to the socially optimal quality level under the decentralized dispute system is $|\frac{1}{2\alpha} - q^*| \geq |\frac{1}{2\alpha} - q^+|$. We first show that given that $q^+ \geq q^*$, for $|\frac{1}{2\alpha} - q^*| \geq |\frac{1}{2\alpha} - q^+|$ to be true, it has to be the case that $\frac{1}{2\alpha} \geq q^*$. We prove this by contradiction. Suppose that $\frac{1}{2\alpha} < q^*$, and also that $|\frac{1}{2\alpha} - q^*| \geq |\frac{1}{2\alpha} - q^+|$. In this case, $|\frac{1}{2\alpha} - q^*| = q^* - \frac{1}{2\alpha}$. Moreover, since $q^+ \geq q^*$, we have $q^+ > \frac{1}{2\alpha}$, and hence $|\frac{1}{2\alpha} - q^+| = q^+ - \frac{1}{2\alpha}$. Thus, taking the difference between the distances of the equilibrium quality levels to the socially optimal level, we have $|\frac{1}{2\alpha} - q^*| - |\frac{1}{2\alpha} - q^+| = (q^* - \frac{1}{2\alpha}) - (q^+ - \frac{1}{2\alpha}) = q^* - q^+ \leq 0$. This is a contradiction. Therefore, $\frac{1}{2\alpha} \geq q^*$ for $|\frac{1}{2\alpha} - q^*| \geq |\frac{1}{2\alpha} - q^+|$.

We next consider the distances of the equilibrium quality levels to the socially optimal level under the three cases identified in Figure 1.2. We first consider Case 1 where dispute does not occur under either system (i.e., $\alpha \leq \underline{\alpha}_d$). Under this case, recall from Propositions 1.1 and 1.3 that $q^* = \frac{4\sigma\theta(y+\sigma)}{\gamma+4\sigma\theta}$ and $q^+ = y+\sigma$. If $q^+ \leq \frac{1}{2\alpha}$, then $|\frac{1}{2\alpha} - q^*| - |\frac{1}{2\alpha} - q^+| = q^+ - q^* \geq 0$ as $q^+ \geq q^*$. If $q^+ > \frac{1}{2\alpha}$, then

$$\begin{aligned}\left|\frac{1}{2\alpha} - q^*\right| - \left|\frac{1}{2\alpha} - q^+\right| &= \left(\frac{1}{2\alpha} - q^*\right) - \left(q^+ - \frac{1}{2\alpha}\right) \\ &= \frac{1}{\alpha} - q^* - q^+ \\ &= \frac{1}{2\alpha} - \frac{(y+\sigma)(\gamma+8\sigma\theta)}{\gamma+4\sigma\theta} \end{aligned} \tag{A.32}$$

where the last step follows from substituting in $q^* = \frac{4\sigma\theta(y+\sigma)}{\gamma+4\sigma\theta}$ and $q^+ = y+\sigma$. Thus, for $|\frac{1}{2\alpha} - q^*| - |\frac{1}{2\alpha} - q^+| \geq 0$, we have from Equation (A.32) that

$$\begin{aligned}&\frac{1}{2\alpha} - \frac{(y+\sigma)(\gamma+8\sigma\theta)}{\gamma+4\sigma\theta} \geq 0 \\ \Leftrightarrow\ & y \leq \frac{(\gamma+4\sigma\theta)}{2\alpha(\gamma+8\sigma\theta)} - \sigma.\end{aligned}$$

Let $y_1 = \frac{(\gamma+4\sigma\theta)}{2\alpha(\gamma+8\sigma\theta)} - \sigma$. Therefore, $|\frac{1}{2\alpha} - q^*| - |\frac{1}{2\alpha} - q^+| \geq 0$ if and only if $y \leq y_1$. Moreover, $y_1$ is decreasing in $\alpha$ as $\frac{\partial y_1}{\partial \alpha} = -\frac{(\gamma+4\sigma\theta)}{2\alpha^2(\gamma+8\sigma\theta)} < 0$.

We next consider Case 2 where dispute occurs only under the decentralized dispute system (i.e., $\underline{\alpha}_d < \alpha \leq \underline{\alpha}_c$). Under this case, recall from Propositions 1.1 and 1.3 that $q^* = \frac{4\sigma\theta(y+\sigma)}{\gamma+4\sigma\theta}$ and $q^+ = \frac{1-\gamma}{2\alpha} + y - \sigma$. If $q^+ \leq \frac{1}{2\alpha}$, then $|\frac{1}{2\alpha} - q^*| - |\frac{1}{2\alpha} - q^+| = q^+ - q^* \geq 0$. If $q^+ > \frac{1}{2\alpha}$, then

$$\begin{aligned}\left|\frac{1}{2\alpha} - q^*\right| - \left|\frac{1}{2\alpha} - q^+\right| &= \left(\frac{1}{2\alpha} - q^*\right) - \left(q^+ - \frac{1}{2\alpha}\right) \\ &= -\frac{\gamma(y-\sigma) + 8\sigma\theta y}{\gamma+4\sigma\theta} + \frac{1+\gamma}{2\alpha}\end{aligned} \tag{A.33}$$

where the last step follows from substituting in $q^* = \frac{4\sigma\theta(y+\sigma)}{\gamma+4\sigma\theta}$ and $q^+ = \frac{1-\gamma}{2\alpha} + y - \sigma$.

Thus, for $|\frac{1}{2\alpha} - q^*| - |\frac{1}{2\alpha} - q^+| \geq 0$, we have from Equation (A.33) that

$$\begin{aligned} &-\frac{\gamma(y-\sigma)+8\sigma\theta y}{\gamma+4\sigma\theta}+\frac{1+\gamma}{2\alpha}\geq 0 \\ &\Leftrightarrow y \leq \frac{1}{\gamma+8\sigma\theta}\left(\frac{(1+\gamma)(\gamma+4\sigma\theta)}{2\alpha}+\gamma\sigma\right). \end{aligned}$$

Let $y_2 = \frac{1}{\gamma+8\sigma\theta}(\frac{(1+\gamma)(\gamma+4\sigma\theta)}{2\alpha} + \gamma\sigma)$. Therefore, $|\frac{1}{2\alpha} - q^*| - |\frac{1}{2\alpha} - q^+| \geq 0$ if and only if $y \leq y_2$. Moreover, $y_2$ is decreasing in $\alpha$ as $\frac{\partial y_2}{\partial \alpha} = -\frac{(1+\gamma)(\gamma+4\sigma\theta)}{2\alpha^2(\gamma+8\sigma\theta)} < 0$.

Lastly, we consider Case 3 where dispute occurs under both systems (i.e., $\alpha > \underline{\alpha}_c$). Under this case, recall from Propositions 1.1 and 1.3 that $q^* = \frac{(1-\gamma)\theta(2\alpha(y-\sigma)+(1-\gamma))}{2\alpha(\gamma\alpha+(1-\gamma)\theta)}$ and $q^+ = \frac{1-\gamma}{2\alpha} + y - \sigma$. Similar to Cases 1 and 2, if $q^+ \leq \frac{1}{2\alpha}$, then $|\frac{1}{2\alpha} - q^*| - |\frac{1}{2\alpha} - q^+| = \frac{1}{\alpha} + q^+ - q^* \geq 0$. If $q^+ > \frac{1}{2\alpha}$, then

$$\begin{aligned} \left|\frac{1}{2\alpha}-q^*\right|-\left|\frac{1}{2\alpha}-q^+\right| &= \left(\frac{1}{2\alpha}-q^*\right)-\left(q^+-\frac{1}{2\alpha}\right) \\ &= \frac{\alpha(\gamma(\gamma+1-2\sigma\theta)+2(1-\gamma)\theta y+2\sigma\theta)+2(1-\gamma)\gamma\theta}{2\alpha(\gamma\alpha+(1-\gamma)\theta)}+\sigma-y, \end{aligned} \tag{A.34}$$

where the last step follows from substituting in $q^* = \frac{(1-\gamma)\theta(2\alpha(y-\sigma)+(1-\gamma))}{2\alpha(\gamma\alpha+(1-\gamma)\theta)}$ and $q^+ = \frac{1-\gamma}{2\alpha} + y - \sigma$. Thus, for $|\frac{1}{2\alpha} - q^*| - |\frac{1}{2\alpha} - q^+| \geq 0$, we have from Equation (A.34) that

$$\begin{aligned} &\frac{\alpha(\gamma(\gamma+-2\sigma\theta)-2(1-\gamma)\theta y+2\sigma\theta)+2(1-\gamma)\gamma\theta}{2\alpha(\gamma\alpha+(1-\gamma)\theta)}+\sigma-y\geq 0 \\ &\Leftrightarrow y \leq \frac{1}{2}\gamma\left(\frac{1}{\gamma\alpha+2(1-\gamma)\theta}+\frac{1}{\alpha}\right)+\sigma. \end{aligned}$$

Let $y_3 = \frac{1}{2}\gamma(\frac{1}{\gamma\alpha+2(1-\gamma)\theta} + \frac{1}{\alpha}) + \sigma$. Therefore, $|\frac{1}{2\alpha} - q^*| - |\frac{1}{2\alpha} - q^+| \geq 0$ if and only if $y \leq y_3$. Moreover, $y_3$ is decreasing in $\alpha$ as $\frac{\partial y_3}{\partial \alpha} = -\frac{\gamma}{2}(\frac{\gamma}{(\gamma\alpha+2(1-\gamma)\theta)^2} + \frac{1}{\alpha^2}) < 0$.

Therefore, given that $q^+ \geq q^*$, combining the three cases, we have $|\frac{1}{2\alpha} - q^*| -$

$|\frac{1}{2\alpha} - q^+| \geq 0$ if and only if $y \leq \bar{y}(\alpha)$, where $\bar{y}(\alpha)$ is defined as

$$\bar{y}(\alpha) = \begin{cases} y_1 & \text{if } q^+ > \frac{1}{2\alpha} \text{ and } \alpha \leq \underline{\alpha}_d \\ y_2 & \text{if } q^+ > \frac{1}{2\alpha} \text{ and } \underline{\alpha}_d < \alpha \leq \underline{\alpha}_c \\ y_3 & \text{if } q^+ > \frac{1}{2\alpha} \text{ and } \alpha > \underline{\alpha}_c \\ \infty & \text{if } q^+ \leq \frac{1}{2\alpha} \end{cases}$$

$$= \begin{cases} \frac{(\gamma+4\sigma\theta)}{2\alpha(\gamma+8\sigma\theta)} - \sigma & \text{if } q^+ > \frac{1}{2\alpha} \text{ and } \alpha \leq \underline{\alpha}_d, \\ \frac{1}{\gamma+8\sigma\theta}\left(\frac{(1+\gamma)(\gamma+4\sigma\theta)}{2\alpha} + \gamma\sigma\right) & \text{if } q^+ > \frac{1}{2\alpha} \text{ and } \underline{\alpha}_d < \alpha \leq \underline{\alpha}_c, \\ \frac{1}{2}\gamma\left(\frac{1}{\gamma\alpha+2(1-\gamma)\theta} + \frac{1}{\alpha}\right) + \sigma & \text{if } q^+ > \frac{1}{2\alpha} \text{ and } \alpha > \underline{\alpha}_c, \\ \infty & \text{if } q^+ \leq \frac{1}{2\alpha}. \end{cases}$$

Finally, we prove that $\bar{y}(\alpha)$ is decreasing in $\alpha$ within the same equilibrium regime (i.e., Case 1, Case 2, or Case 3). Under each case, we have already shown that $\bar{y}(\alpha)$ is decreasing in $\alpha$ when $\bar{y}(\alpha) = y_1$ (under Case 1), $\bar{y}(\alpha) = y_2$ (under Case 2), and $\bar{y}(\alpha) = y_3$ (under Case 3). To prove that the monotonicity preserves when incorporating the scenario of $\bar{y}(\alpha) = \infty$, we need to show that within each equilibrium regime, as $\alpha$ increases, the relationship of $q^+$ and $\frac{1}{2\alpha}$ can only change from $q^+ \leq \frac{1}{2\alpha}$ to $q^+ > \frac{1}{2\alpha}$, but not the other way around. This can be guaranteed if $\frac{1}{2\alpha} - q^+$ is decreasing in $\alpha$. Under Case 1, $\frac{1}{2\alpha} - q^+ = \frac{1}{2\alpha} - (y+\sigma)$, which is decreasing in $\alpha$. Under Cases 2 and 3, $\frac{1}{2\alpha} - q^+ = \frac{\gamma}{2\alpha} - y + \sigma$, which is also decreasing in $\alpha$. Thus, $\bar{y}(\alpha)$ is decreasing in $\alpha$ within the same equilibrium regime, and the proof is complete. □

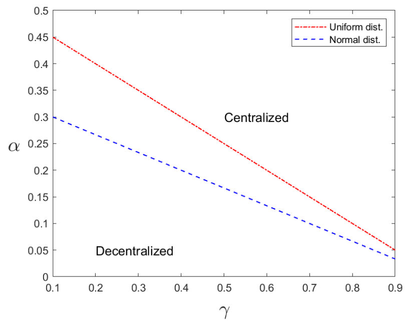
## A.5 Numerical Results

In this section, we conduct numerical analyses to verify the robustness of the main result of comparing the platform's equilibrium utilities under the centralized and decentralized dispute systems. Recall that Theorem 1.3 is proved under the conditions of $\gamma \leq \frac{1}{3}$ and $\sigma \leq y$. We remove these conditions in our numerical analyses. In Figure A.1, we show the $\bar{\alpha}$ threshold as a function of $\gamma$. In each sub-figure, we vary the values of other parameters such as $\theta$, $y$ and $\sigma$. Furthermore, to test the robustness of our results with respect to the distribution of the evaluated quality, we consider two types of distributions: uniform and truncated normal (both with support $y - \sigma$ to $y + \sigma$).

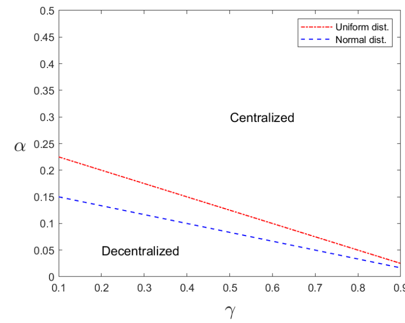
From Figure A.1, we observe that the optimal strategy continues to be characterized by a single threshold $\bar{\alpha}$ above which the decentralized dispute system dominates the centralized dispute system, and vice versa. Thus, our main insights are robust when we extend beyond the conditions required in Theorem 1.3. Moreover, the value of $\bar{\alpha}$ follows a similar trend when the evaluated quality follows a uniform distribution or a truncated normal distribution, suggesting that our insights are also robust with respect to the specific distribution in use.

Figure A.1: $\alpha$ threshold for the platform's optimal dispute system.

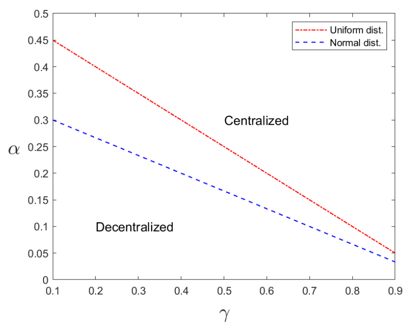
(a) $\theta = 0.01$, $y = 2$ and $\sigma = 1$



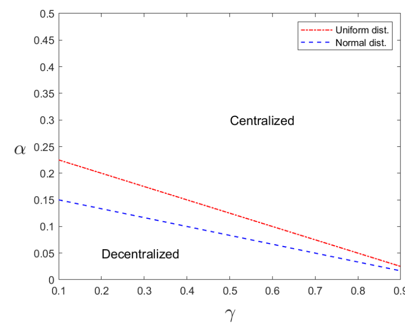

(b) $\theta = 0.01$, $y = 2$ and $\sigma = 4$



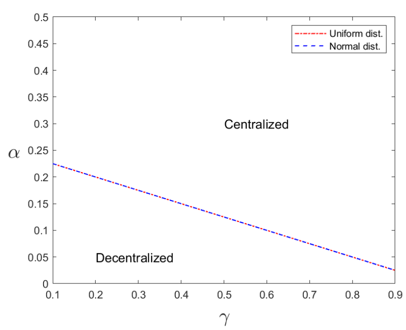

(c) $\theta = 0.05$, $y = 2$ and $\sigma = 1$



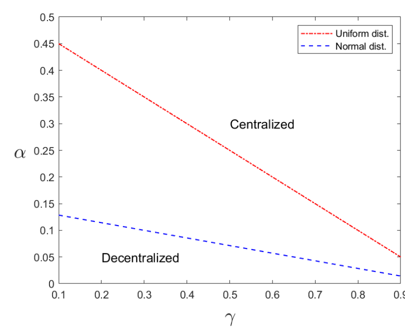

(d) $\theta = 0.05$, $y = 2$ and $\sigma = 4$



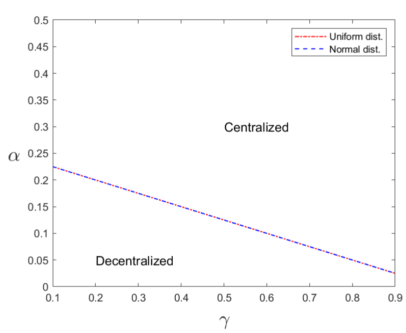

(e) $\theta = 0.01$, $y = 3$ and $\sigma = 1$



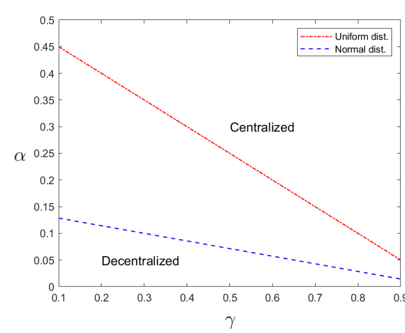

(f) $\theta = 0.01$, $y = 3$ and $\sigma = 4$




(g) $\theta = 0.05$, $y = 3$ and $\sigma = 1$




(h) $\theta = 0.05$, $y = 3$ and $\sigma = 4$



## A.6 Proofs of Section 1.9.1 (Third-Party Arbitration)

*Proof of Lemma 1.3* Given that the third-party arbitration is initiated, the arbitrator decides on the threshold $k_a$ to evaluate the freelancer's work. As the arbitrator's utility is given by $-\zeta_y(k_a - y)^2 - \zeta_k(k_a - k)^2$, taking the first order condition of the arbitrator's utility with respect to $k_a$, we have

$$k_a^* = \frac{\zeta_y y + \zeta_k k}{\zeta_y + \zeta_k}.$$

Since the arbitrator makes a binding decision on the dispute based on the threshold $k_a^*$, the probability of the freelancer winning the dispute is given by

$$\begin{aligned} h_a^*(q) &= h(q, k_a^*) \\ &= \begin{cases} 0 & \text{if } q \leq k_a^* - \sigma, \\ \frac{q - k_a^* + \sigma}{2\sigma} & \text{if } k_a^* - \sigma < q < k_a^* + \sigma, \\ 1 & \text{if } q \geq k_a^* + \sigma. \end{cases} \end{aligned} \tag{A.35}$$

At stage 7, the client and the freelancer decide whether to appeal the platform's decision. Recall that only the party that loses in the platform's dispute decision may appeal. If the freelancer loses the dispute and does not appeal, his utility is given by

$$U_f(q) = -\alpha q^2 - f.$$

If he loses the dispute and appeals, his utility is given by

$$U_f(q) = -\alpha q^2 - h_a^*(q)(1 - \gamma)p - f.$$

Therefore, the freelancer always appeals. If the client loses the dispute and does not appeal, her utility is given by

$$U_c(p) = q - p.$$

If she loses the dispute and appeals, her utility is given by

$$U_c(p) = q - h_a^*(q)p.$$

Therefore, the client always appeals. Hence, both parties always appeal.

At Stage 6, the platform makes a non-binding decision on the dispute, which will only occur if the client has rejected the freelancer's work and the freelancer has initiated the dispute. The freelancer wins the dispute with probability $h(q,k)$ and loses with probability $1-h(q,k)$. Since the platform knows that the loser of the platform's ruling will always appeal, the eventual winning probability of the freelancer is given by $h_a^*(q)$. In this case, the platform's utility if dispute occurs is

$$\begin{aligned}\Pi(k,f) &= h_a^*(q)\gamma p + f - \theta(k-y)^2 \\ &= \frac{q - \frac{\zeta_y y + \zeta_k k}{\zeta_y + \zeta_k} + \sigma}{2\sigma}\gamma p + f - \theta(k-y)^2.\end{aligned}$$

where the second step follows from substituting in Equation (A.35) and $k_a^*$. Taking the first order condition of the above equation with respect to $k$, the threshold utilized by the platform to judge the freelancer's work is given by

$$k_t^* = y - \frac{\gamma p \zeta_k}{4\sigma\theta(\zeta_y + \zeta_k)},$$

and thus, $k_a^*$ is given by

$$k_a^* = y - \frac{\gamma p \zeta_k^2}{4\sigma\theta(\zeta_y + \zeta_k)^2} = y - \frac{\gamma p \tau^2}{4\sigma\theta},$$

where the last step follows from $\tau = \frac{\zeta_k}{\zeta_y + \zeta_k}$. Therefore, the winning probability of the freelancer is given by

$$h_a^*(q) = \begin{cases} 0 & \text{if } q \leq k_a^* - \sigma, \\ \frac{q-y+\sigma}{2\sigma} + \frac{\gamma p \tau^2}{8\sigma^2\theta} & \text{if } k_a^* - \sigma < q < k_a^* + \sigma, \\ 1 & \text{if } q \geq k_a^* + \sigma. \end{cases} \tag{A.36}$$

which is increasing in $q$ and $\tau$. □

*Proof of Proposition 1.4* Proposition 1.4 can be proven by backward induction based on the decision tree in Figure 1.3.

At Stage 6, the platform makes a decision on the dispute, which will only occur if the client has rejected the freelancer's work and the freelancer has initiated the dispute. Based on Lemma 1.3, the freelancer wins the dispute with probability $h_a^*(q)$ and loses with probability $1 - h_a^*(q)$.

At Stage 5, the freelancer makes the decision on whether to initiate the dispute, which will only occur if the client has rejected the freelancer's work. The freelancer's utility is given by

$$U_f(q) = \begin{cases} -\alpha q^2 + h_a^*(q)(1-\gamma)p - f & \text{if dispute is initiated,} \\ -\alpha q^2 & \text{if dispute is not initiated.} \end{cases}$$

Therefore, the freelancer initiates the dispute if $h_a^*(q)(1-\gamma)p - f \geq 0$, and does not initiate the dispute otherwise.

At Stage 4, the client decides whether to accept or reject the freelancer's work. If the client accepts the freelancer's work, her utility is

$$U_c(p) = q - p.$$

If the client rejects the freelancer's work, her utility is

$$U_c(p) = \begin{cases} q - h_a^*(q)p & \text{if } h_a^*(q)(1-\gamma)p - f \geq 0, \\ q & \text{if } h_a^*(q)(1-\gamma)p - f < 0. \end{cases}$$

Therefore, if $h_a^*(q)(1-\gamma)p - f \geq 0$, the client accepts if $h_a^*(q) = 1$ and rejects if $h_a^*(q) < 1$. If $h_a^*(q)(1-\gamma)p - f < 0$, the client always rejects since $q \geq q - h_a^*(q)p \geq q - p$.

The client's utility is then given by

$$U_c(p) = \begin{cases} q - p & \text{if } h_a^*(q) = 1 \text{ and } h_a^*(q)(1-\gamma)p - f \geq 0, \\ q - h_a^*(q)p & \text{if } h_a^*(q) < 1 \text{ and } h_a^*(q)(1-\gamma)p - f \geq 0, \\ q & \text{if } h_a^*(q)(1-\gamma)p - f < 0. \end{cases}$$

At Stage 3, the freelancer decides whether to participate or not and chooses his quality level if he participates. If $h_a^*(q)(1-\gamma)p - f < 0$, the client always rejects and the freelancer does not initiate the dispute. Thus, the freelancer does not participate if $h_a^*(q)(1-\gamma)p - f < 0$, which is equivalent to choosing $q_t^* = 0$. If $h_a^*(q)(1-\gamma)p - f \geq 0$, the freelancer's utility is

$$U_f(q) = \begin{cases} -\alpha q^2 + (1-\gamma)p & \text{if } h_a^*(q) = 1, \\ -\alpha q^2 + h_a^*(q)(1-\gamma)p - f & \text{if } h_a^*(q) < 1. \end{cases}$$

Note that when $h_a^*(q) = 0$, the freelancer's utility is negative. Thus, from Lemma 1.1, $q \leq k_a^* - \sigma$ cannot be an equilibrium.

If $h_a^*(q) = 1$, we have $q \geq k_a^* + \sigma = y + \sigma - \frac{\gamma p \zeta_k^2}{4\sigma\theta(\zeta_y+\zeta_k)^2}$ from Equation (A.36). Since the freelancer's utility is decreasing in $q$, he chooses the lowest possible $q$ such that

$$q_t^* = y + \sigma - \frac{\gamma p \zeta_k^2}{4\sigma\theta(\zeta_y + \zeta_k)^2}. \tag{A.37}$$

Therefore, the freelancer's utility is $U_{f,1} = -\alpha(y + \sigma - \frac{\gamma p \zeta_k^2}{4\sigma\theta(\zeta_y+\zeta_k)^2})^2 + (1-\gamma)p$.

If $h_a^*(q) < 1$, we have $h_a^*(q) = \frac{q-y+\sigma}{2\sigma} + \frac{\gamma p \zeta_k^2}{8\sigma^2\theta(\zeta_y+\zeta_k)^2}$ from Equation (A.36) and thus, the freelancer's utility is concave in $q$. The freelancer chooses $q$ based on the first order condition of his utility such that

$$q_t^* = \frac{(1-\gamma)p}{4\sigma\alpha}. \tag{A.38}$$

Therefore, the freelancer's utility is $U_{f,2} = -\alpha(\frac{(1-\gamma)p}{4\sigma\alpha})^2 + h_a^*(\frac{(1-\gamma)p}{4\sigma\alpha})(1-\gamma)p - f$.

Thus, the freelancer does not initiate the dispute if

$$
\begin{aligned}
&U_{f,1} - U_{f,2} \\
=&\frac{-\left(-\alpha\gamma p\zeta_k^2 + 4\alpha\sigma\theta(\sigma + y)(\zeta_y + \zeta_k)^2 + (\gamma - 1)p\theta(\zeta_y + \zeta_k)^2\right)^2 + 16\alpha\sigma^2\theta^2 f(\zeta_y + \zeta_k)^4}{16\alpha\sigma^2\theta^2(\zeta_y + \zeta_k)^4} \\
\geq& 0.
\end{aligned}
$$

Note that the quality chosen in Equation (A.38) is equal to that in Equation (A.37) (i.e., $\frac{(1-\gamma)p}{4\sigma\alpha} = y+\sigma-\frac{\gamma p\zeta_k^2}{4\sigma\theta(\zeta_y+\zeta_k)^2}$) at $\alpha = \frac{(1-\gamma)p\theta(\zeta_y+\zeta_k)^2}{4\sigma\theta(y+\sigma)(\zeta_y+\zeta_k)^2-\gamma p\zeta_k^2}$. If $\alpha \leq \frac{(1-\gamma)p\theta(\zeta_y+\zeta_k)^2}{4\sigma\theta(y+\sigma)(\zeta_y+\zeta_k)^2-\gamma p\zeta_k^2}$, the quality chosen based on Equation (A.2) is greater than Equation (A.1). In this case, we have $U_{f,1} \geq U_{f,2}$, since $h_a^*(q) = 1$ for $q \geq k_a^* + \sigma = y + \sigma - \frac{\gamma p\zeta_k^2}{4\sigma\theta(\zeta_y+\zeta_k)^2}$ from Equation (A.36) and the quality cost under $U_{f,2}$ is higher. Thus, the dispute is not initiated. Moreover, notice that the numerator of $U_{f,1} - U_{f,2}$ is quadratic downwards in terms of $\alpha$ and hence, there exist two roots to $U_{f,1}-U_{f,2} = 0$. Since at $\alpha = \frac{(1-\gamma)p\theta(\zeta_y+\zeta_k)^2}{4\sigma\theta(y+\sigma)(\zeta_y+\zeta_k)^2-\gamma p\zeta_k^2}$, $U_{f,1} - U_{f,2} \geq 0$. Thus, the other root must be greater than $\alpha = \frac{(1-\gamma)p\theta(\zeta_y+\zeta_k)^2}{4\sigma\theta(y+\sigma)(\zeta_y+\zeta_k)^2-\gamma p\zeta_k^2}$. Therefore, there exists a threshold $\underline{\alpha}_{ct} \geq \frac{(1-\gamma)p\theta(\zeta_y+\zeta_k)^2}{4\sigma\theta(y+\sigma)(\zeta_y+\zeta_k)^2-\gamma p\zeta_k^2}$, such that $U_{f,1} - U_{f,2} \geq 0$ if $\alpha \leq \underline{\alpha}_{ct}$. Hence, if $h_a^*(q)(1-\gamma)p - f \geq 0$, the freelancer's optimal quality level is

$$
q_t^* = \begin{cases} y + \sigma - \frac{\gamma p\zeta_k^2}{4\sigma\theta(\zeta_y+\zeta_k)^2} & \text{if } \alpha \leq \underline{\alpha}_{ct}, \\ \frac{(1-\gamma)p}{4\sigma\alpha} & \text{if } \alpha > \underline{\alpha}_{ct}. \end{cases}
$$

Moreover, the freelancer participates if $U_f \geq 0$ and does not participate if $U_f < 0$.

At Stage 2, the client decides whether to participate or not and if she participates, she chooses the price to offer to the freelancer, subject to the freelancer's individual rationality constraint.

(a) If $\alpha \leq \underline{\alpha}_{ct}$ and $h_a^*(q_t^*)(1-\gamma)p - f \geq 0$, we have $h_a^*(q_t^*) = 1$ and $q_t^* = y + \sigma -$

$\frac{\gamma p \zeta_k^2}{4\sigma\theta(\zeta_y+\zeta_k)^2}$. As dispute does not occur in this case, the client's problem is

$$\max_{p\geq 0} \quad q_t^* - p,$$
$$\text{s.t.} \quad -\alpha(q_t^*)^2 + (1-\gamma)p \geq 0.$$

Since the client's utility is decreasing in $p$, $p$ is chosen such that $(1-\gamma)p - f \geq 0$ and $-\alpha(q_t^*)^2 + (1-\gamma)p \geq 0$ for the freelancer to participate. Therefore, $p_t^* = \max(\frac{\alpha(y+\sigma-\frac{\gamma p_t^* \zeta_k^2}{4\sigma\theta(\zeta_y+\zeta_k)^2})^2}{1-\gamma}, \frac{f}{1-\gamma})$.

(b) If $\alpha > \underline{\alpha}_{ct}$ and $h_a^*(q_t^*)(1-\gamma)p - f \geq 0$, we have $h_a^*(q_t^*) < 1$ and $q_t^* = \frac{(1-\gamma)p}{4\sigma\alpha}$. As dispute occurs in this case, the client's problem is

$$\max_{p\geq 0} \quad q_t^* - h_a^*(q_t^*)p,$$
$$\text{s.t.} \quad -\alpha(q_t^*)^2 + h_a^*(q_t^*)(1-\gamma)p - f \geq 0.$$

We first consider the case where the individual rationality constraint of the freelancer is binding. Let $\bar{p}_{ct}$ be the price at which the individual rationality constraint of the freelancer is binding, i.e., $\bar{p}_{ct}$ is the solution of $U_f(q_t^*) = -\alpha(q_t^*)^2 + h_a^*(q_t^*)(1-\gamma)\bar{p}_{ct} - f = 0$. Using the Envelope Theorem, $\frac{\partial U_f}{\partial \bar{p}_{ct}} = h_a^*(q_t^*)(1-\gamma) + \frac{\gamma\zeta_k^2}{8\theta\sigma^2(\zeta_y+\zeta_k)^2}(1-\gamma)\bar{p}_{ct} > 0$ and $\frac{\partial U_f}{\partial f} = -1 < 0$. As such, using the Implicit Function Theorem,

$$\frac{\partial \bar{p}_{ct}}{\partial f} = -\frac{\frac{\partial U_f}{\partial f}}{\frac{\partial U_f}{\partial \bar{p}_{ct}}} > 0. \tag{A.39}$$

We next define $\hat{p}_{ct}$ as the solution to the unconstrained client's problem. Taking the derivative of the client's utility, we have

$$\begin{aligned}\frac{\partial U_c}{\partial p} &= \frac{\partial q_t^*}{\partial p} - \left[\left(\frac{\partial h_a^*(q_t^*)}{\partial q_t^*}\frac{\partial q_t^*}{\partial p} + \frac{\partial h_a^*(q_t^*)}{\partial p}\right)p + h_a^*(q_t^*)\right] \\ &= \frac{1-\gamma}{4\sigma\alpha} - \left[\left(\frac{1-\gamma}{8\sigma^2\alpha} + \frac{\gamma\zeta_k^2}{8\theta\sigma^2(\zeta_y+\zeta_k)^2}\right)p + h_a^*(q_t^*)\right],\end{aligned}$$

where the last step follows from differentiating Equation (A.38) and differentiating Equation (A.36). Therefore, $\frac{\partial U_c}{\partial p}\Big|_{p=0} = \frac{1-\gamma}{4\sigma\alpha} - h_a^*(q_t^*)$ is positive as $h_a^*(q_t^*) \leq$

$\frac{q_t^*}{p} = \frac{1-\gamma}{4\sigma\alpha}$ from the individual rationality constraint of the client (i.e., $U_c \geq 0$) and Equation (A.38). Thus, we must have $\hat{p}_{ct} \geq 0$ if the client participates.

Since $\bar{p}_{ct}$ is increasing in $f$ from Equation (A.39) and $\hat{p}_{ct}$ is constant in $f$, there exists a threshold $\underline{f}_{ct}$ such that $\hat{p}_{ct} = \bar{p}_{ct}$ and

$$p_t^* = \begin{cases} \hat{p}_{ct} & \text{if } f \leq \underline{f}_{ct}, \\ \bar{p}_{ct} & \text{if } f > \underline{f}_{ct}. \end{cases}$$

At $f = \underline{f}_{ct}$, rearranging the binding individual rationality constraint of the freelancer, we obtain $\bar{p}_{ct} = \frac{\underline{f}_{ct} + \alpha(q_t^*)^2}{h_a^*(q_t^*)(1-\gamma)}$, which is increasing in $\underline{f}_{ct}$. Therefore, the client's utility is $U_c = q_t^* - \frac{\underline{f}_{ct} + \alpha(q_t^*)^2}{(1-\gamma)}$, which is non-negative if and only if $\underline{f}_{ct} \leq (1-\gamma)(q_t^*) - \alpha(q_t^*)^2$. Therefore, if $\underline{f}_{ct} \leq (1-\gamma)(q_t^*) - \alpha(q_t^*)^2$, the client's offer price is

$$p_t^* = \begin{cases} \hat{p}_{ct} & \text{if } f \leq \underline{f}_{ct}, \\ \frac{f + \alpha(q_t^*)^2}{h_a^*(q_t^*)(1-\gamma)} & \text{if } f > \underline{f}_{ct}. \end{cases} \tag{A.40}$$

Moreover, the client participates if $q_t^* - h_a^*(q_t^*)p_t^* \geq 0$, and does not participate if $q_t^* - h_a^*(q_t^*)p_t^* < 0$. In both cases, the individual rationality constraint of the freelancer depends on the dispute fee $f$.

At Stage 1, the platform chooses the dispute fee $f$ while satisfying the individual rationality constraints of the client and the freelancer.

(a) Recall from previous analyses that if $\alpha \leq \underline{\alpha}_{ct}$, dispute does not occur. The freelancer chooses quality $q_t^* = y + \sigma - \frac{\gamma p^* \zeta_k^2}{4\theta\sigma(\zeta_y+\zeta_k)^2}$ and the client offers price $p_t^* = \max(\frac{\alpha(y+\sigma-\frac{\gamma p_t^* \zeta_k^2}{4\theta\sigma(\zeta_y+\zeta_k)^2})^2}{1-\gamma}, \frac{f}{1-\gamma})$. Thus, the platform will achieve a utility of $\Pi(f) = \gamma p_t^* = \gamma \max(\frac{\alpha(y+\sigma-\frac{\gamma p_t^* \zeta_k^2}{4\theta\sigma(\zeta_y+\zeta_k)^2})^2}{1-\gamma}, \frac{f}{1-\gamma})$. Hence, the platform's optimization problem is as follows:

$$\max_{f\geq 0} \quad \gamma \max\left(\frac{\alpha(y+\sigma-\frac{\gamma p_t^* \zeta_k^2}{4\theta\sigma(\zeta_y+\zeta_k)^2})^2}{1-\gamma}, \frac{f}{1-\gamma}\right),$$

$$\text{s.t.} \quad \left(y+\sigma-\frac{\gamma p_t^* \zeta_k^2}{4\theta\sigma(\zeta_y+\zeta_k)^2}\right) - \max\left(\frac{\alpha(y+\sigma-\frac{\gamma p_t^* \zeta_k^2}{4\theta\sigma(\zeta_y+\zeta_k)^2})^2}{1-\gamma}, \frac{f}{1-\gamma}\right) \geq 0, \tag{A.41}$$

$$-\alpha\left(y+\sigma-\frac{\gamma p_t^* \zeta_k^2}{4\theta\sigma(\zeta_y+\zeta_k)^2}\right)^2 + (1-\gamma)\max\left(\frac{\alpha(y+\sigma-\frac{\gamma p_t^* \zeta_k^2}{4\theta\sigma(\zeta_y+\zeta_k)^2})^2}{1-\gamma}, \frac{f}{1-\gamma}\right) \geq 0, \tag{A.42}$$

where Equation (A.41) is the individual rationality constraint of the client, and Equation (A.42) is the individual rationality constraint of the freelancer.

Notice from the above problem formulation that the case of $\frac{f}{1-\gamma} \leq \frac{\alpha(y+\sigma-\frac{\gamma p_t^* \zeta_k^2}{4\theta\sigma(\zeta_y+\zeta_k)^2})^2}{1-\gamma}$ is equivalent to $\frac{f}{1-\gamma} = \frac{\alpha(y+\sigma-\frac{\gamma p_t^* \zeta_k^2}{4\theta\sigma(\zeta_y+\zeta_k)^2})^2}{1-\gamma}$. We thus focus on $\frac{f}{1-\gamma} \geq \frac{\alpha(y+\sigma-\frac{\gamma p_t^* \zeta_k^2}{4\theta\sigma(\zeta_y+\zeta_k)^2})^2}{1-\gamma}$, or equivalently, $f \geq \alpha(y+\sigma-\frac{\gamma p_t^* \zeta_k^2}{4\theta\sigma(\zeta_y+\zeta_k)^2})^2$. In this case, the platform's utility reduces to $\Pi = \frac{\gamma f}{1-\gamma}$, Equation (A.41) reduces to $f \leq (1-\gamma)(y+\sigma-\frac{\gamma p_t^* \zeta_k^2}{4\theta\sigma(\zeta_y+\zeta_k)^2})$, and Equation (A.42) reduces to $f \geq \alpha(y+\sigma-\frac{\gamma p_t^* \zeta_k^2}{4\theta\sigma(\zeta_y+\zeta_k)^2})^2$. Thus, if $\alpha(y+\sigma-\frac{\gamma p_t^* \zeta_k^2}{4\theta\sigma(\zeta_y+\zeta_k)^2})^2 > (1-\gamma)(y+\sigma-\frac{\gamma p_t^* \zeta_k^2}{4\theta\sigma(\zeta_y+\zeta_k)^2})$, or equivalently, $y+\sigma-\frac{\gamma p_t^* \zeta_k^2}{4\theta\sigma(\zeta_y+\zeta_k)^2} > \frac{1-\gamma}{\alpha}$, the problem is infeasible. If $y+\sigma-\frac{\gamma p_t^* \zeta_k^2}{4\theta\sigma(\zeta_y+\zeta_k)^2} \leq \frac{1-\gamma}{\alpha}$, since $\Pi$ is increasing in $f$, we have

$$f_t^* = (1-\gamma)(y+\sigma-\frac{\gamma p_t^* \zeta_k^2}{4\theta\sigma(\zeta_y+\zeta_k)^2}), \tag{A.43}$$

which also satisfies $f_t^* \geq \alpha(y+\sigma-\frac{\gamma p_t^* \zeta_k^2}{4\theta\sigma(\zeta_y+\zeta_k)^2})^2$. Since $p_t^* = \frac{f}{1-\gamma}$, from Equation (A.43) we have $p_t^* = y+\sigma-\frac{\gamma p_t^* \zeta_k^2}{4\theta\sigma(\zeta_y+\zeta_k)^2} = q_t^*$. Therefore, $p_t^*$ is given by

$$p_t^* = \frac{4\sigma\theta(y+\sigma)(\zeta_y+\zeta_k)^2}{\gamma\zeta_k^2 + 4\sigma\theta(\zeta_y+\zeta_k)^2},$$

and $q_t^*$ is given by

$$q_t^* = \frac{4\sigma\theta(y+\sigma)(\zeta_y+\zeta_k)^2}{\gamma\zeta_k^2 + 4\sigma\theta(\zeta_y+\zeta_k)^2}.$$

Hence, the platform's equilibrium utility is $\Pi_t^* = \gamma p_t^* = \frac{4\gamma\sigma\theta(y+\sigma)(\zeta_y+\zeta_k)^2}{\gamma\zeta_k^2+4\sigma\theta(\zeta_y+\zeta_k)^2}$. Note that if we let $\theta_t = \frac{(\zeta_y+\zeta_k)^2}{\zeta_k^2}\theta$, we can re-express the platform's utility as $\Pi_t^* = \frac{4\gamma\sigma\theta_t(y+\sigma)}{\gamma+4\sigma\theta_t}$, which is of the similar form as the main model with $\theta$ being replaced by $\theta_t$.

Finally, we derive the threshold $\underline{\alpha}_{ct}$. Recall that the freelancer does not initiate the dispute if $U_{f,1} - U_{f,2} \geq 0$. As $p_t^* = \frac{f_t^*}{1-\gamma}$, if the freelancer initiates the dispute (i.e., choosing $q < \frac{4\sigma\theta(y+\sigma)(\zeta_y+\zeta_k)^2}{\gamma\zeta_k^2+4\sigma\theta(\zeta_y+\zeta_k)^2}$), the freelancer's utility is $U_{f,2} = -\alpha q^2 + h_a^*(q)(1-\gamma)p_t^* - f_t^* = -\alpha q^2 - (1 - h_a^*(q))f_t^* \leq 0$. Therefore, the condition $U_{f,1} - U_{f,2} \geq 0$ is always satisfied by the freelancer's individual rationality constraint (i.e., Equation (A.42)). Thus, the condition can be re-expressed as $\alpha \leq \underline{\alpha}_{ct} = \frac{1-\gamma}{q_t^*} = \frac{(1-\gamma)(\gamma\zeta^2+4\sigma\theta(\zeta_y+\zeta_k)^2)}{4\sigma\theta(y+\sigma)(\zeta_y+\zeta_k)^2}$.

(b) Recall from previous analyses that if $\alpha > \underline{\alpha}_{ct}$, dispute occurs. The freelancer chooses quality $q_t^* = \frac{(1-\gamma)p_t^*}{4\sigma\alpha}$ and the client offers price $p^*$ based on Equation (A.40). Hence, the platform's optimization problem is as follows:

$$\max_{f\geq 0} \quad h_a^*(q_t^*)\gamma p_t^* + f - \theta(k_t^* - y)^2,$$

$$\text{s.t.} \quad q_t^* - h_a^*(q_t^*)p_t^* \geq 0, \tag{A.44}$$

$$-\alpha(q_t^*)^2 + h_a^*(q_t^*)(1-\gamma)p_t^* - f \geq 0, \tag{A.45}$$

where Equation (A.44) is the individual rationality constraint of the client, and Equation (A.45) is the individual rationality constraint of the freelancer. Recall that $k_t^* = y - \frac{\gamma p^* \zeta_k}{4\theta\sigma(\zeta_y+\zeta_k)}$. Thus, $\Pi$ can be equivalently expressed as $\Pi(f) = h_a^*(q_t^*)\gamma p_t^* + f - \frac{\gamma^2(p_t^*)^2\zeta_k^2}{16\theta\sigma^2(\zeta_y+\zeta_k)^2}$.

Recall from Stage 2(b) that if $\underline{f}_{ct} \leq (1-\gamma)(q_t^*) - \alpha(q_t^*)^2$, $U_c \geq 0$. Since $\frac{\partial U_c}{\partial f}\Big|_{p=\bar{p}_{ct}} = \frac{\partial U_c}{\partial p}\Big|_{p=\bar{p}_{ct}}\frac{\partial \bar{p}_{ct}}{\partial f} < 0$, $U_c$ is decreasing in $f$. Thus, there exists a threshold $\bar{f}_{ct}$, where $\bar{f}_{ct} > \underline{f}_{ct}$, such that $U_c \geq 0$ if and only if $f \leq \bar{f}_{ct}$. Moreover, we have shown previously that $U_c = 0$ if $f = (1-\gamma)(q_t^*) - \alpha(q_t^*)^2$, and thus, $\bar{f}_{ct} = (1-\gamma)q_t^* - \alpha(q_t^*)^2$.

Therefore, there are three possible cases of $f$, which are defined as follows:

Case b.1: $f \le \underline{f}_{ct} < \bar{f}_{ct} \Rightarrow U_f \ge 0$ and $U_c \ge 0$,

Case b.2: $\underline{f}_{ct} < f \le \bar{f}_{ct} \Rightarrow U_f = 0$ and $U_c \ge 0$,

Case b.3: $f > \bar{f}_{ct} \Rightarrow$ No contracting occurs.

Under Case b.1, since $f \le \underline{f}_{ct}$, $p_t^* = \hat{p}_{ct}$ and $q_t^*$ are both constant in $f$. This implies that the platform's utility $\Pi$ is increasing in $f$. As such, $f_t^* = \underline{f}_{ct}$, under which $U_f = 0$ and $U_c > 0$. Under Case b.2, since $f > \underline{f}_{ct}$ and $f \le \bar{f}_{ct}$, $p_t^* = \bar{p}_{ct}$ and $q_t^*$ both depend on $f$. The derivative of $h_a^*(q_t^*)$ with respect to $f$ is given by

$$\begin{aligned}
\frac{\partial h_a^*(q_t^*)}{\partial f} &= \frac{\partial h_a^*(q_t^*)}{\partial q_t^*}\frac{\partial q_t^*}{\partial f} + \frac{\partial h_a^*(q_t^*)}{\partial \bar{p}_{ct}}\frac{\partial \bar{p}_{ct}}{\partial f} \\
&= \left[\frac{\partial h_a^*(q_t^*)}{\partial q_t^*}\frac{\partial q_t^*}{\partial \bar{p}_{ct}} + \frac{\partial h_a^*(q_t^*)}{\partial \bar{p}_{ct}}\right]\frac{\partial \bar{p}_{ct}}{\partial f} \\
&= \left(\frac{1-\gamma}{8\sigma^2\alpha} + \frac{\gamma\zeta_k^2}{8\theta\sigma^2(\zeta_y+\zeta_k)^2}\right)\frac{\partial \bar{p}_{ct}}{\partial f},
\end{aligned} \tag{A.46}$$

where the second step follows from applying the chain rule to $\frac{\partial q_t^*}{\partial f}$, and the last step follows from differentiating Equation (A.38) and differentiating Equation (A.36). The derivative of $\Pi$ with respect to $f$ is given by

$$\begin{aligned}
\frac{\partial \Pi}{\partial f} &= \gamma\left[\frac{\partial h_a^*(q_t^*)}{\partial f}\bar{p}_{ct} + h_a^*(q_t^*)\frac{\partial \bar{p}_{ct}}{\partial f}\right] + 1 - \frac{\gamma^2\bar{p}_{ct}\zeta_k^2}{8\theta\sigma^2(\zeta_y+\zeta_k)^2}\frac{\partial \bar{p}_{ct}}{\partial f} \\
&= \gamma\left[\left(\frac{1-\gamma}{8\sigma^2\alpha} + \frac{\gamma\zeta_k^2}{8\theta\sigma^2(\zeta_y+\zeta_k)^2}\right)\frac{\partial \bar{p}_{ct}}{\partial f}\bar{p}_{ct} + h_a^*(q_t^*)\frac{\partial \bar{p}_{ct}}{\partial f}\right] + 1 - \frac{\gamma^2\bar{p}_{ct}\zeta_k^2}{8\theta\sigma^2(\zeta_y+\zeta_k)^2}\frac{\partial \bar{p}_{ct}}{\partial f} \\
&= \gamma\left[\frac{(1-\gamma)\bar{p}_{ct}}{8\sigma^2\alpha} + h_a^*(q_t^*)\right]\frac{\partial \bar{p}_{ct}}{\partial f} + 1 \\
&> 0,
\end{aligned}$$

where the second step follows from substituting $\frac{\partial h_a^*(q_t^*)}{\partial f}$ with Equation (A.46), and the last step follows from $\frac{\partial \bar{p}_{ct}}{\partial f} > 0$ based on Equation (A.39). Since $\Pi$ is increasing in $f$ throughout Case b.1 and Case b.2, the optimal dispute fee is $f_t^* = \bar{f}_{ct}$, under which $U_f^* = U_c^* = 0$. Consequently, the optimal dispute fee is

$$f_t^* = (1-\gamma)q_t^* - \alpha(q_t^*)^2, \tag{A.47}$$

and from the binding individual rationality constraint of the client in Equation (A.44), we obtain the client's equilibrium the offer price is $p_t^* = \frac{q_t^*}{h_a^*(q_t^*)}$. From Equation (A.38), we obtain $q_t^* = \frac{(1-\gamma)p_t^*}{4\alpha\sigma}$. Substituting $q_t^*$ into Equation (A.44), we have

$$
\begin{aligned}
& q_t^* - h_a^*(q_t^*)p_t^* = 0 \\
\Leftrightarrow\ & q_t^* - \left(\frac{q_t^* - y + \sigma}{2\sigma} + \frac{\gamma p_t^* \zeta_k^2}{8\theta\sigma^2(\zeta_y + \zeta_k)^2}\right) p_t^* = 0 \\
\Leftrightarrow\ & \frac{(1-\gamma)p_t^*}{4\alpha\sigma} - \left(\frac{\frac{(1-\gamma)p_t^*}{4\alpha\sigma} - y + \sigma}{2\sigma} + \frac{\gamma p_t^* \zeta_k^2}{8\theta\sigma^2(\zeta_y + \zeta_k)^2}\right) p_t^* = 0 \\
\Leftrightarrow\ & p_t^* = \frac{2\sigma\theta(2\alpha(y-\sigma) + (1-\gamma))(\zeta_y + \zeta_k)^2}{\gamma\alpha\zeta_k^2 + (1-\gamma)\theta(\zeta_y + \zeta_k)^2},
\end{aligned}
$$

where the first step follows substituting in Equation (A.36) and the second step follows from $q_t^* = \frac{(1-\gamma)p_t^*}{4\alpha\sigma}$. Therefore, from Equation (A.38), we have

$$
q_t^* = \frac{(1-\gamma)\theta(2\alpha(y-\sigma) + (1-\gamma))(\zeta_y + \zeta_k)^2}{2\alpha\left(\gamma\alpha\zeta_k^2 + (1-\gamma)\theta(\zeta_y + \zeta_k)^2\right)},
$$

and from Equation (A.11), we have

$$
\begin{aligned}
f_t^* =& \frac{1}{4\alpha(\gamma\alpha\zeta_k^2 + (1-\gamma)\theta(\zeta_y + \zeta_k)^2)^2}\Big[(1-\gamma)^2\theta(\zeta_y + \zeta_k)^2(2\alpha(y-\sigma) \\
& + (1-\gamma))(2\alpha(\gamma\zeta_k^2 - \theta(y-\sigma)(\zeta_y + \zeta_k)^2) + (1-\gamma)\theta(\zeta_y + \zeta_k)^2)\Big].
\end{aligned} \tag{A.48}
$$

Therefore, the platform's utility is

$$
\begin{aligned}
\Pi^* =& h_a^*(q_t^*)\gamma p_t^* + f_t^* - \frac{\gamma^2(p_t^*)^2\zeta_k^2}{16\theta\sigma^2(\zeta_y + \zeta_k)^2} \\
=& \frac{1}{4\alpha(\gamma\alpha\zeta_k^2 + (1-\gamma)\theta(\zeta_y + \zeta_k)^2)^2}\Big[\theta(\zeta_y + \zeta_k)^2(2\alpha(y-\sigma) + (1-\gamma))\Big(-2\gamma^2\alpha^2(y-\sigma)\zeta_k^2 \\
& - \alpha(1-\gamma)(\zeta_k^2(\gamma(\gamma + 2\sigma\theta - 2) + 2(1-\gamma)\theta y - 2\sigma\theta) + 4(1-\gamma)\theta\zeta_k\zeta_y(y-\sigma) \\
& + 2(1-\gamma)\theta\zeta_y^2(y-\sigma)) - (1-\gamma)^2(\gamma + 1)\theta(\zeta_y + \zeta_k)^2\Big)\Big] \\
=& \frac{1}{4\alpha(\gamma\alpha + (1-\gamma)\theta_t)^2}\Big[\theta_t(2\alpha(y-\sigma) + (1-\gamma))\Big(-2\gamma^2\alpha^2(y-\sigma) \\
& + (1-\gamma)\alpha((2-\gamma)\gamma - 2\gamma\sigma\theta_t - 2(1-\gamma)\theta_t y + 2\sigma\theta_t) + (1+\gamma)(1-\gamma)^2\theta_t\Big)\Big],
\end{aligned}
$$

where the second step follows from substituting in $q_t^*$, $p_t^*$ and $f_t^*$, and the third step follows from letting $\theta_t = \frac{(\zeta_y+\zeta_k)^2}{\zeta_k^2}\theta$. Thus, $\Pi_t^*$ can be expressed in a similar form as the main model with $\theta$ being replaced by $\theta_t$.

Moreover, since $f_t^* = q_t^*((1-\gamma) - \alpha q_t^*) \geq 0$ for contracting to occur, if $\sigma > y$, $f_t^* = 0$ at $\alpha = \frac{1-\gamma}{2(\sigma-y)}$. If $\sigma \leq y - \frac{\gamma\zeta_k^2}{\theta(\zeta_y+\zeta_k)^2}$, from Equation (A.12), $f_t^* = 0$ at $\alpha = \frac{(1-\gamma)\theta(\zeta_y+\zeta_k)^2}{2(\theta(y-\sigma)(\zeta_y+\zeta_k)^2-\gamma\zeta_k^2)}$. If $y - \frac{\gamma\zeta_k^2}{\theta(\zeta_y+\zeta_k)^2} < \sigma \leq y$, $f_t^* \geq 0$ for all $\alpha$. Therefore, if dispute occurs, there exists a threshold, $\hat{\alpha}_{ct}$, such that $f_t^* \geq 0$ if and only if $\alpha \leq \hat{\alpha}_{ct}$, where $\hat{\alpha}_{ct}$ is given by

$$\hat{\alpha}_{ct} = \begin{cases} \frac{(1-\gamma)\theta(\zeta_y+\zeta_k)^2}{2(\theta(y-\sigma)(\zeta_y+\zeta_k)^2-\gamma\zeta_k^2)} & \text{if } \sigma \leq y - \frac{\gamma\zeta_k^2}{\theta(\zeta_y+\zeta_k)^2}, \\ \infty & \text{if } y - \frac{\gamma\zeta_k^2}{\theta(\zeta_y+\zeta_k)^2} < \sigma \leq y, \\ \frac{1-\gamma}{2(\sigma-y)} & \text{if } \sigma > y. \end{cases}$$

If $\alpha > \hat{\alpha}_{ct}$, since the dispute fee has to be non-negative, setting $f_t^* = 0$ would cause the individual rationality constraint of the freelancer to be violated. We define $\bar{\alpha}_{ct} = \max(\underline{\alpha}_{ct}, \hat{\alpha}_{ct})$. Contracting occurs in equilibrium if and only if $\alpha \leq \bar{\alpha}_{ct}$. Thus, given that contracting occurs, dispute occurs in equilibrium if and only if $\underline{\alpha}_{ct} < \alpha \leq \bar{\alpha}_{ct}$.

Finally, we compare the thresholds to the main model. Comparing $\underline{\alpha}_{ct}$ with $\underline{\alpha}_c$, We have $\underline{\alpha}_{ct} - \underline{\alpha}_c = \frac{(1-\gamma)\gamma\zeta_y(\zeta_y+2\zeta_k)}{4\sigma\theta(y+\sigma)(\zeta_y+\zeta_k)^2} \leq 0$ and thus, $\underline{\alpha}_{ct} \leq \underline{\alpha}_c$. To compare $\bar{\alpha}_{ct}$ and $\bar{\alpha}_c$, we compare $\hat{\alpha}_{ct}$ and $\hat{\alpha}_c$ as $\bar{\alpha}_{cd} = \max(\underline{\alpha}_{cd}, \hat{\alpha}_c)$ and $\bar{\alpha}_c = \max(\underline{\alpha}_c, \hat{\alpha}_c)$. Since $\hat{\alpha}_{ct} = \hat{\alpha}_c$ if $\sigma > y - \frac{\gamma\zeta_k^2}{\theta(\zeta_y+\zeta_k)^2}$, we just need to compare under the case of $\sigma \leq y - \frac{\gamma\zeta_k^2}{\theta(\zeta_y+\zeta_k)^2}$. If $y - \frac{\gamma}{\theta} < \sigma \leq y - \frac{\gamma\zeta_k^2}{\theta(\zeta_y+\zeta_k)^2}$, since $\hat{\alpha}_c \to \infty$ and $\hat{\alpha}_{ct} = \frac{(1-\gamma)\theta(\zeta_y+\zeta_k)^2}{2(\theta(y-\sigma)(\zeta_y+\zeta_k)^2-\gamma\zeta_k^2)}$, we have $\hat{\alpha}_{ct} < \hat{\alpha}_c$. If $\sigma \leq y - \frac{\gamma}{\theta} < \sigma$, we have $\hat{\alpha}_{ct} - \hat{\alpha}_c = -\frac{(1-\gamma)\gamma\theta\zeta_y(\zeta_y+2\zeta_k)}{2(\theta(y-\sigma)-\gamma)(\theta(y-\sigma)(\zeta_y+\zeta_k)^2-\gamma\zeta_k^2)} \leq 0$. Therefore, combining all cases, we have $\bar{\alpha}_{ct} = \max(\underline{\alpha}_{cd}, \hat{\alpha}_c) \leq \max(\underline{\alpha}_c, \hat{\alpha}_c) = \bar{\alpha}_c$. □

*Proof of Theorem 1.5* Following the proof of Proposition 1.4, we note that if we let $\theta_t = \frac{(\zeta_y+\zeta_k)^2}{\zeta_k^2}\theta$, the platform's utility under the centralized dispute system with third-party arbitration remains the same as the main model with $\theta$ being replaced by $\theta_t$. In this case, the comparison of $\Pi_t^*$ from Proposition 1.4 and $\Pi^+$ from Proposition 1.3 follows directly from the proof of Theorem 1.3 with $\theta$ being replaced by $\theta_t$. Let $\bar{\sigma}_t = \frac{\sqrt{(\gamma+2\theta_t y)^2+16\gamma\theta_t y}-\gamma+2\theta_t y}{12\theta_t}$ and $\bar{\bar{\alpha}}_t$ be the solution of Equation (A.31) with $\theta$ being replaced by $\theta_t$. Thus, we have $\Pi^+ \geq \Pi_t^*$ if and only if $\alpha \leq \bar{\alpha}_t$, where

$$\bar{\alpha}_t = \begin{cases} \bar{\alpha}_d & \text{if } \sigma \leq \bar{\sigma}_t, \\ \min(\bar{\alpha}_d, \max(\underline{\alpha}_{ct}, \bar{\bar{\alpha}}_t)) & \text{if } \bar{\sigma}_t < \sigma \leq y. \end{cases}$$

Finally, we derive some properties of $\bar{\alpha}_t$ with respect to $\tau$. Notice that $\bar{\alpha}_t$ is constant in $\tau$ if $\bar{\alpha}_t = \bar{\alpha}_d$. Hence, we only need to examine the properties of $\underline{\alpha}_{ct}$ and $\bar{\bar{\alpha}}_t$. Note that the ratio $\tau = \frac{\zeta_k}{\zeta_y+\zeta_k}$ is increasing in $\zeta_k$ since $\frac{\partial\tau}{\partial\zeta_k} = \frac{\zeta_y}{(\zeta_y+\zeta_k)} > 0$. Thus, it is sufficient to examine $\bar{\alpha}_t$ with respect to $\zeta_k$.

If $\bar{\alpha}_t = \underline{\alpha}_{ct}$, differentiating $\bar{\alpha}_t$ with respect to $\zeta_k$, we have $\frac{\partial\bar{\alpha}_t}{\partial\zeta_k} = \frac{(1-\gamma)\gamma\zeta_k\zeta_y}{2\sigma\theta(y+\sigma)(\zeta_y+\zeta_k)^3} \geq 0$. Thus, $\bar{\alpha}_t$ is increasing in $\zeta_k$ and $\tau$.

If $\bar{\alpha}_t = \bar{\bar{\alpha}}_t$, differentiating $\bar{\alpha}_t$ with respect to $\theta_t$, we have

$$\frac{\partial\bar{\alpha}_t}{\partial\theta_t} = -\frac{-\frac{2(\sigma-y)\left(\gamma\left(3\gamma^2+6(3\gamma-4)\sigma\theta-7\gamma+2\right)-2(2-3\gamma)^2\theta y+8\sigma\theta\right)}{\sqrt{24(\gamma-1)\gamma^2\theta(\sigma-y)+\left(\gamma^2-6\gamma\sigma\theta+6\gamma\theta y+\gamma+4\sigma\theta-4\theta y\right)^2}} + 6\gamma(\sigma-y) + 4(y-\sigma)}{4\gamma(y-\sigma)}$$

Differentiating again with respect to $\theta_t$, we have

$$\begin{aligned}\frac{\partial^2\bar{\alpha}_t}{\partial\theta_t^2} =& \frac{24(1-\gamma)\gamma^2(1-2\gamma)(y-\sigma)}{\left(24(\gamma-1)\gamma^2\theta(\sigma-y)+(\gamma^2-6\gamma\sigma\theta+6\gamma\theta y+\gamma+4\sigma\theta-4\theta y)^2\right)^{3/2}} \\ &> 0,\end{aligned}$$

where the last step follows from $\gamma \leq \frac{1}{3}$ and $\sigma \leq y$. We next show that $\frac{\partial\bar{\alpha}_t}{\partial\theta_t} < 0$ for large $\theta_t$, and thus, $\frac{\partial\bar{\alpha}_t}{\partial\theta_t} < 0$ for all $\theta_t$. Since $\bar{\bar{\alpha}}_t$ is the solution of Equation (A.31) with $\theta$ being replaced by $\theta_t$, we have

$$-2\gamma\bar{\alpha}_t^2(y-\sigma) + \bar{\alpha}_t\left(\gamma^2 + \gamma(1-6\sigma\theta_t+6\theta y) - 4\theta_t(y-\sigma)\right) + 3(1-\gamma)\gamma\theta_t = 0.$$

Let $H = -2\gamma\bar{\alpha}_t^2(y-\sigma) + \bar{\alpha}_t\left(\gamma^2 + \gamma(1-6\sigma\theta_t+6\theta y) - 4\theta_t(y-\sigma)\right) + 3(1-\gamma)\gamma\theta_t$. Differentiating $H$ with respect to $\theta_t$, we have

$$\begin{aligned}\frac{\partial H}{\partial \theta_t} &= 3\gamma(1-\gamma) - \bar{\alpha}_t(4-6\gamma)(y-\sigma) \\ &\leq 3\gamma(1-\gamma) + \frac{(1-\gamma)(4-6\gamma)(y-\sigma)}{(y+\sigma)} \\ &= -\frac{(1-\gamma)((-4+\gamma)\sigma + (4-9\gamma)y)}{y+\sigma} \\ &\leq -\frac{4(1-\gamma)(y-\sigma)}{y+\sigma} \\ &\leq 0,\end{aligned}$$

where the second step follows from the expression being the biggest at $\bar{\alpha}_t = \underline{\alpha}_d$ (i.e., the threshold where dispute starts to occur under the decentralized dispute system) since $\frac{\partial}{\partial\bar{\alpha}_t}(3\gamma(1-\gamma) - \alpha(4-6\gamma)(y-\sigma)) = -(4-6\gamma)(y-\sigma) < 0$ as $\gamma \leq \frac{1}{3}$ and $\sigma \leq y$, the third step follows from re-arranging the terms, the fourth step follows from the term $(-4+\gamma)\sigma + (4-9\gamma)y$ being the biggest at $\gamma = 0$ since $\frac{\partial}{\partial\alpha}((-4+\gamma)\sigma + (4-9\gamma)y) = 3\sigma - 9y < 0$, and the last step follows from $\sigma \leq y$. Next, differentiating $H$ with respect to $\bar{\alpha}_t$, we have

$$\begin{aligned}\frac{\partial H}{\partial \bar{\alpha}_t} &= \gamma(1+\gamma) - 2\gamma(2\bar{\alpha}_t - 3\theta_t)(y-\sigma) - 4\theta_t(y-\sigma) \\ &\leq \gamma(1+\gamma) - 2\gamma(2\frac{1-\gamma}{y+\sigma} - 3\theta_t)(y-\sigma) - 4\theta_t(y-\sigma) \\ &= \frac{2}{9}\left(-2 - 9\theta_t(y-\sigma) + \frac{8\sigma}{y+\sigma}\right) \\ &< 0,\end{aligned}$$

where the second step follows from the expression being the biggest at $\bar{\alpha}_t = \underline{\alpha}_d$ since $\frac{\partial}{\partial\bar{\alpha}_t}(\gamma(1+\gamma) - 2\gamma(2\bar{\alpha}_t - 3\theta)(y-\sigma) - 4\theta_t(y-\sigma)) = -4\gamma(y-\sigma) < 0$ as $\sigma \leq y$, the third step follows from re-arranging the terms, and the last step follows from $\theta_t > \frac{2(3\sigma-y)}{9(y^2-\sigma^2)}$, which can be re-expressed as $\theta \geq \frac{2(3\sigma-y)\zeta_k^2}{9(y^2-\sigma^2)(\zeta_y+\zeta_k)^2}$. Hence, if $\theta > \frac{2(3\sigma-y)\zeta_k^2}{9(y^2-\sigma^2)(\zeta_y+\zeta_k)^2}$, using the Implicit Function Theorem, we have $\frac{\partial\bar{\alpha}_t}{\partial\theta_t} = -\frac{\frac{\partial H}{\partial\theta_t}}{\frac{\partial H}{\partial\bar{\alpha}_t}} < 0$. Since

$\frac{\partial^2 \bar{\alpha}_t}{\partial \theta_t^2} > 0$ and $\frac{\partial \bar{\alpha}_t}{\partial \theta_t} < 0$ for large $\theta_t$, $\frac{\partial \bar{\alpha}_t}{\partial \theta_t} < 0$ for all $\theta_t$. Moreover, as $\frac{\partial \theta_t}{\partial \zeta_k} = -\frac{2\theta\zeta_y(\zeta_k+\zeta_y}{\zeta_k^3} < 0$, we have $\frac{\partial \bar{\alpha}_t}{\partial \zeta_k} = \frac{\partial \bar{\alpha}_t}{\partial \theta_t}\frac{\partial \theta_t}{\partial \zeta_k} > 0$. Thus, combining all cases, $\bar{\alpha}_t$ is increasing in $\zeta_k$ and $\tau$.

□

## A.7 Proofs of Section 1.9.2 (Price-Dependent Industry Standard)

*Proof of Proposition 1.5* The analysis for Stages 3 to 6 follows from the Proof of Proposition 1.1 since the utilities of the freelancer and the client remain the same with $y$ being replaced by $y = y_0 + \eta p$. Hence, at Stage 3, if $h^*(q)(1-\gamma)p - f \geq 0$, the freelancer's optimal quality level is

$$q_p^* = \begin{cases} y_0 + \eta p + \sigma - \frac{\gamma p}{4\theta\sigma} & \text{if } \alpha \leq \underline{\alpha}_{cp}, \\ \frac{(1-\gamma)p}{4\sigma\alpha} & \text{if } \alpha > \underline{\alpha}_{cp}. \end{cases}$$

Moreover, the freelancer participates if $U_f \geq 0$ and does not participate if $U_f < 0$.

At Stage 2, the client decides whether to participate or not and if she participates, she chooses the price to offer to the freelancer, subject to the freelancer's individual rationality constraint.

(a) If $\alpha \leq \underline{\alpha}_{cp}$ and $h^*(q^*)(1-\gamma)p - f \geq 0$, we have $h^*(q_p^*) = 1$ and $q_p^* = y_0 + \eta p + \sigma - \frac{\gamma p}{4\theta\sigma}$. As dispute does not occur in this case, the client's problem is

$$\begin{aligned} \max_{p \geq 0} \quad & q_p^* - p, \\ \text{s.t.} \quad & -\alpha(q_p^*)^2 + (1-\gamma)p \geq 0. \end{aligned}$$

Since the client's utility is decreasing in $p$, $p$ is chosen such that $(1-\gamma)p - f \geq 0$ and $-\alpha(q_p^*)^2 + (1-\gamma)p \geq 0$ for the freelancer to participate. Therefore, $p_p^* = \max(\frac{\alpha(y_0+\eta p_p^*+\sigma-\frac{\gamma p_p^*}{4\theta\sigma})^2}{1-\gamma}, \frac{f}{1-\gamma})$.

(b) If $\alpha > \underline{\alpha}_{cp}$ and $h^*(q^*)(1-\gamma)p - f \geq 0$, we have $h^*(q_p^*) < 1$ and $q_p^* = \frac{(1-\gamma)p}{4\sigma\alpha}$. As dispute occurs in this case, the client's problem is

$$\max_{p\geq 0} \quad q_p^* - h^*(q_p^*)p,$$
$$\text{s.t.} \quad -\alpha(q_p^*)^2 + h^*(q_p^*)(1-\gamma)p - f \geq 0.$$

We first consider the case where the individual rationality constraint of the freelancer is binding. Let $\bar{p}_{cp}$ be the price at which the individual rationality constraint of the freelancer is binding, i.e., $\bar{p}_{cp}$ is the solution of $U_f(q_p^*) = -\alpha(q_p^*)^2 + h^*(q_p^*)(1-\gamma)\bar{p}_{cp} - f = 0$. Using the Envelope Theorem, $\frac{\partial U_f}{\partial \bar{p}_{cp}} > 0$ and $\frac{\partial U_f}{\partial f} < 0$. As such, using the Implicit Function Theorem, $\frac{\partial \bar{p}_{cp}}{\partial f} = -\frac{\frac{\partial U_f}{\partial f}}{\frac{\partial U_f}{\partial \bar{p}_{cp}}} > 0$. We next define $\hat{p}_{cp}$ as the solution to the unconstrained client's problem. Since $\bar{p}_c$ is increasing in $f$ and $\hat{p}_{cp}$ is constant in $f$, there exists a threshold $\underline{f}_{cp}$ such that $\hat{p}_{cp} = \bar{p}_{cp}$ and

$$p_p^* = \begin{cases} \hat{p}_{cp} & \text{if } f \leq \underline{f}_{cp}, \\ \bar{p}_{cp} & \text{if } f > \underline{f}_{cp}. \end{cases}$$

At Stage 1, the platform chooses the dispute fee $f$ while satisfying the individual rationality constraints of the client and the freelancer.

(a) Recall from previous analyses that if $\alpha \leq \underline{\alpha}_{cp}$, dispute does not occur. The freelancer chooses quality $q_p^* = y_0 + \eta p^* + \sigma - \frac{\gamma p_p^*}{4\theta\sigma}$ and the client offers price $p_p^* = \max(\frac{\alpha(y_0+\eta p_p^*+\sigma-\frac{\gamma p_p^*}{4\theta\sigma})^2}{1-\gamma}, \frac{f}{1-\gamma})$. Thus, the platform will achieve a utility of $\Pi(f) = \gamma p_p^* = \gamma \max(\frac{\alpha(y_0+\eta p^*+\sigma-\frac{\gamma p_p^*}{4\theta\sigma})^2}{1-\gamma}, \frac{f}{1-\gamma})$. Thus, the platform's optimization problem is as follows:

$$\max_{f\geq 0} \quad \gamma \max\left(\frac{\alpha(y_0+\eta p_p^*+\sigma-\frac{\gamma p_p^*}{4\theta\sigma})^2}{1-\gamma}, \frac{f}{1-\gamma}\right),$$

$$\text{s.t.} \quad \left(y_0+\eta p_p^*+\sigma-\frac{\gamma p_p^*}{4\theta\sigma}\right) - \max\left(\frac{\alpha(y_0+\eta p_p^*+\sigma-\frac{\gamma p_p^*}{4\theta\sigma})^2}{1-\gamma}, \frac{f}{1-\gamma}\right) \geq 0, \tag{A.49}$$

$$-\alpha\left(y_0+\eta p_p^*+\sigma-\frac{\gamma p_p^*}{4\theta\sigma}\right)^2 + (1-\gamma)\max\left(\frac{\alpha(y_0+\eta p_p^*+\sigma-\frac{\gamma p_p^*}{4\theta\sigma})^2}{1-\gamma}, \frac{f}{1-\gamma}\right) \geq 0, \tag{A.50}$$

where Equation (A.49) is the individual rationality constraint of the client, and Equation (A.50) is the individual rationality constraint of the freelancer. Notice that this platform's problem is similar to the platform's problem in solving for the optimal dispute fee under the centralized dispute system in the main model. Thus, we have $f_p^* = (1-\gamma)p_p^*$ and $p_p^* = q_p^*$. Therefore, $q_p^*$ is given by

$$q_p^* = y_0 + \eta q_p^* + \sigma - \frac{\gamma q_p^*}{4\theta\sigma}$$
$$\Leftrightarrow q_p^* = \frac{4\sigma\theta(y_0+\sigma)}{\gamma+4\sigma\theta(1-\eta)}.$$

Moreover, from the individual rationality constraint of the freelancer, we obtain $\underline{\alpha}_{cp} = \frac{(1-\gamma)(\gamma+4\sigma\theta(1-\eta))}{4\sigma\theta(y_0+\sigma)}$. Hence, if $\alpha \leq \underline{\alpha}_{cp}$, the platform's equilibrium utility is $\Pi_p^* = \gamma p_p^* = \gamma q_p^* = \frac{4\gamma\sigma\theta(y_0+\sigma)}{\gamma+4\sigma\theta(1-\eta)}$.

(b) Recall from previous analyses that if $\alpha > \underline{\alpha}_{cp}$, dispute occurs. The platform's optimization problem is as follows:

$$\max_{f\geq 0} \quad h^*(q_p^*)\gamma p_p^* + f - \theta(k^*-y)^2,$$

$$\text{s.t.} \quad q_p^* - h^*(q_p^*)p_p^* \geq 0, \tag{A.51}$$

$$-\alpha(q_p^*)^2 + h^*(q_p^*)(1-\gamma)p_p^* - f \geq 0, \tag{A.52}$$

where Equation (A.51) is the individual rationality constraint of the client, and Equation (A.52) is the individual rationality constraint of the freelancer. Notice that the analysis for the equilibrium outcome follows from the proof of Proposition 1.1. Thus, the platform's expected utility is increasing in $f$ and the platform chooses the optimal $f$ such that both Equations (A.51) and (A.52) are binding. Substituting $q_p^*$ into Equation (A.51), we have

$$\begin{aligned}
& q_p^* - h_p^*(q_p^*)p_p^* = 0 \\
\Leftrightarrow\ & q_p^* - \left(\frac{q_p^* - y_0 - \eta p_p^* + \sigma}{2\sigma} + \frac{\gamma p_p^*}{8\theta\sigma^2}\right)p_p^* = 0 \\
\Leftrightarrow\ & \frac{(1-\gamma)p_p^*}{4\alpha\sigma} - \left(\frac{\frac{(1-\gamma)p_p^*}{4\alpha\sigma} - y - \eta p_p^* + \sigma}{2\sigma} + \frac{\gamma p_p^*}{8\theta\sigma^2}\right)p_p^* = 0 \\
\Leftrightarrow\ & p_p^* = \frac{2\sigma\theta(2\alpha(y_0 - \sigma) + (1-\gamma))}{\alpha(\gamma - 4\sigma\theta\eta) + (1-\gamma)\theta},
\end{aligned}$$

and

$$q_p^* = \frac{(1-\gamma)\theta(2\alpha(y_0 - \sigma) + (1-\gamma))}{2\alpha(\alpha(\gamma - 4\sigma\theta\eta) + (1-\gamma)\theta)},$$

and from Equation (A.52), we obtain

$$\begin{aligned}
f_p^* =& -\alpha(q_p^*)^2 + h_p^*(q_p^*)(1-\gamma)p_p^* \\
=& \frac{(1-\gamma)^2\theta(2\alpha(y_0 - \sigma) + (1-\gamma))(2\alpha(\gamma + \theta(\sigma - 4\sigma\eta - y_0)) + (1-\gamma)\theta)}{4\alpha(\alpha(\gamma - 4\sigma\theta\eta) + (1-\gamma)\theta)^2}.
\end{aligned}$$

Therefore, the platform's utility is

$$\begin{aligned}
\Pi_p^* =& h^*(q_p^*)\gamma p_p^* + f_p^* - \frac{\gamma^2(p_p^*)^2}{16\theta\sigma^2} \\
=& \frac{1}{4\alpha(\alpha(\gamma - 4\sigma\theta\eta) - \gamma\theta + \theta)^2}\Big[\theta(2\alpha(y_0 - \sigma) + 1 - \gamma)\Big(2\alpha^2\gamma^2(\sigma - y_0) \\
& + \alpha(\gamma - 1)\left(\gamma^2 + 2\gamma(\sigma\theta - \theta y_0 - 1) + 2\theta(4\sigma\eta - \sigma + y_0)\right) + (\gamma+1)(\gamma-1)^2\theta\Big)\Big].
\end{aligned}$$

Moreover, since dispute fee has to be non-negative for contracting to occur, if $\sigma > y_0$, $f_p^* = 0$ at $\alpha = \frac{1-\gamma}{2(\sigma - y_0)}$. If $\sigma \leq y_0 - \frac{\gamma}{\theta(1-4\eta)}$, $f_p^* = 0$ at $\alpha = \frac{(1-\gamma)\theta}{2(\theta(y_0 + 4\sigma\eta - \sigma) - \gamma)}$. If $y_0 - \frac{\gamma}{\theta(1-4\eta)} < \sigma \leq y_0$, $f_p^* \geq 0$ for all $\alpha$. Therefore, if dispute occurs, there exists a threshold, $\hat{\alpha}_{cp}$, such that $f_p^* \geq 0$ if and only if $\alpha \leq \hat{\alpha}_{cp}$, where $\hat{\alpha}_{cp}$ is given by

$$\hat{\alpha}_{cp} = \begin{cases} \frac{(1-\gamma)\theta}{2(\theta(y_0+4\sigma\eta-\sigma)-\gamma)} & \text{if } \sigma \leq y_0 - \frac{\gamma}{\theta(1-4\eta)}, \\ \infty & \text{if } y_0 - \frac{\gamma}{\theta(1-4\eta)} < \sigma \leq y_0, \\ \frac{1-\gamma}{2(\sigma-y_0)} & \text{if } \sigma > y_0. \end{cases}$$

If $\alpha > \hat{\alpha}_{cp}$, since the dispute fee has to be non-negative, setting $f_p^* = 0$ would cause the individual rationality constraint of the freelancer to be violated. We define $\bar{\alpha}_{cp} = \max(\underline{\alpha}_{cp}, \hat{\alpha}_{cp})$. Contracting occurs if and only if $\alpha \leq \bar{\alpha}_{cp}$. Thus, given that contracting occurs, dispute occurs in equilibrium if and only if $\underline{\alpha}_{cp} < \alpha \leq \bar{\alpha}_{cp}$. □

*Proof of Proposition 1.6* Similar to the proof of Proposition 1.6, the analysis for Stages 3 to 6 follows from the Proof of Proposition 1.3 since the utilities of the freelancer and the client remain the same with $y$ being replaced by $y = y_0 + \eta p$. Hence, at Stage 3, if $h^+(q)(1-\gamma)p - f \geq 0$, the freelancer's optimal quality level is

$$q_p^+ = \begin{cases} y_0 + \eta p + \sigma & \text{if } \alpha \leq \underline{\alpha}_{dp}, \\ \frac{(1-\gamma)p}{4\sigma\alpha} & \text{if } \alpha > \underline{\alpha}_{dp}. \end{cases}$$

Moreover, the freelancer participates if $U_f \geq 0$ and does not participate if $U_f < 0$.

At Stage 2, the client decides whether to participate or not and if she participates, she chooses the price to offer to the freelancer, subject to the freelancer's individual rationality constraint.

(a) If $\alpha \leq \underline{\alpha}_{dp}$ and $h^+(q_p^+)(1-\gamma)p - f \geq 0$, we have $h^+(q_p^+) = 1$ and $q_p^+ = y_0 + \eta p + \sigma$. As dispute does not occur in this case, the client's problem is

$$\max_{p \geq 0} \quad q_p^+ - p,$$
$$\text{s.t.} \quad -\alpha(q_p^+)^2 + (1-\gamma)p \geq 0.$$

Since the client's utility is decreasing in $p$, $p$ is chosen such that $(1-\gamma)p - f \geq 0$ and $-\alpha(q_p^+)^2 + (1-\gamma)p \geq 0$ for the freelancer to participate. Therefore, $p_p^+ = \max(\frac{\alpha(y_0+\eta p_p^+\sigma)^2}{1-\gamma}, \frac{f}{1-\gamma})$.

(b) If $\alpha > \underline{\alpha}_{dp}$ and $h^+(q_p^+)(1-\gamma)p - f \geq 0$, we have $h^+(q_p^+) < 1$ and $q_p^+ = \frac{(1-\gamma)p}{4\sigma\alpha}$. As dispute occurs in this case, the client's problem is

$$\max_{p\geq 0} \quad q_p^+ - h^+(q_p^+)p,$$
$$\text{s.t.} \quad -\alpha(q_p^+)^2 + h^+(q_p^+)(1-\gamma)p - f \geq 0.$$

We first consider the case where the individual rationality constraint of the freelancer is binding. Let $\bar{p}_{dp}$ be the price at which the individual rationality constraint of the freelancer is binding, i.e., $\bar{p}_{dp}$ is the solution of $U_f(q_p^+) = -\alpha(q_p^+)^2 + h^+(q_p^+)(1-\gamma)\bar{p}_{dp} - f = 0$. Using the Envelope Theorem, $\frac{\partial U_f}{\partial \bar{p}_{dp}} > 0$, and $\frac{\partial U_f}{\partial f} < 0$. As such, using the Implicit Function Theorem, $\frac{\partial \bar{p}_{dp}}{\partial f} = -\frac{\frac{\partial U_f}{\partial f}}{\frac{\partial U_f}{\partial \bar{p}_{dp}}} > 0$. We next define $\hat{p}_{dp}$ as the solution to the unconstrained client's problem. Since $\bar{p}_{dp}$ is increasing in $f$ and $\hat{p}_{dp}$ is constant in $f$, there exists a threshold $\underline{f}_{dp}$ such that $\hat{p}_{dp} = \bar{p}_{dp}$ and

$$p_p^+ = \begin{cases} \hat{p}_{dp} & \text{if } f \leq \underline{f}_{dp}, \\ \bar{p}_{dp} & \text{if } f > \underline{f}_{dp}. \end{cases}$$

At Stage 1, the platform chooses the dispute fee $f$ while satisfying the individual rationality constraints of the client and the freelancer.

(a) Recall from previous analyses that if $\alpha \leq \underline{\alpha}_{dp}$, dispute does not occur. The freelancer chooses quality $q_p^+ = y_0 + \eta p^+ + \sigma$ and the client offers price $p_p^+ = \max(\frac{\alpha(y_0+\eta p_p^+ + \sigma)^2}{1-\gamma}, \frac{f}{1-\gamma})$. Thus, the platform will achieve a utility of $\Pi(f) = \gamma p_p^+ =$

$\gamma \max(\frac{\alpha(y_0+\eta p_p^+ +\sigma)^2}{1-\gamma}, \frac{f}{1-\gamma})$. Thus, the platform's optimization problem is as follows:

$$\begin{aligned}
\max_{f\geq 0} \quad & \gamma \max\left(\frac{\alpha(y_0+\eta p_p^+ +\sigma)^2}{1-\gamma}, \frac{f}{1-\gamma}\right),\\
\text{s.t.} \quad & (y_0+\eta p_p^+ +\sigma) - \max\left(\frac{\alpha(y_0+\eta p_p^+ +\sigma)^2}{1-\gamma}, \frac{f}{1-\gamma}\right) \geq 0,\\
& -\alpha(y_0+\eta p_p^+ +\sigma)^2 + (1-\gamma)\max\left(\frac{\alpha(y_0+\eta p_p^+ +\sigma)^2}{1-\gamma}, \frac{f}{1-\gamma}\right) \geq 0,
\end{aligned}$$

Notice that this is similar to the platform's problem in solving for the optimal dispute fee under the decentralized dispute system in the main model. Thus, we have $f_p^+ = (1-\gamma)p_p^+$ and $p_p^+ = q_p^+$. Therefore, $q_p^+$ is given by

$$\begin{aligned}
q_p^+ &= y_0 + \eta q_p^+ + \sigma\\
\Leftrightarrow q_p^+ &= \frac{y_0+\sigma}{1-\eta}.
\end{aligned}$$

Moreover, from the individual rationality constraint of the freelancer, we obtain $\underline{\alpha}_{dp} = \frac{(1-\gamma)(1-\eta)}{y_0+\sigma}$. Hence, if $\alpha \leq \underline{\alpha}_{dp}$, the platform's equilibrium utility is $\Pi_p^+ = \frac{\gamma(y_0+\sigma)}{1-\eta}$.

(b) Recall from previous analyses that if $\alpha > \underline{\alpha}_{dp}$, dispute occurs. The platform's optimization problem is as follows:

$$\begin{aligned}
\max_{f\geq 0} \quad & h^+(q_p^+)\gamma p_p^+ + f,\\
\text{s.t.} \quad & q_p^+ - h^+(q_p^+)p_p^+ \geq 0, && \text{(A.53)}\\
& -\alpha(q_p^+)^2 + h^+(q_p^+)(1-\gamma)p_p^+ - f \geq 0, && \text{(A.54)}
\end{aligned}$$

where Equation (A.53) is the individual rationality constraint of the client, and Equation (A.54) is the individual rationality constraint of the freelancer. Notice that the analysis for the equilibrium outcome follows from the proof of Proposition 1.3. Thus, the platform's expected utility is increasing in $f$ and the platform chooses the optimal $f$ such that both Equations (A.53) and (A.54) are binding.

Substituting $q_p^+$ into Equation (A.53), we have

$$\begin{aligned}
& q_p^+ - h^+(q_p^+)p_p^+ = 0 \\
\Leftrightarrow\ & q_p^+ - \left(\frac{q_p^+ - y_0 - \eta p_p^+ + \sigma}{2\sigma}\right)p_p^+ = 0 \\
\Leftrightarrow\ & \frac{(1-\gamma)p_p^+}{4\alpha\sigma} - \left(\frac{\frac{(1-\gamma)p_p^+}{4\alpha\sigma} - y - \eta p_p^+ + \sigma}{2\sigma}\right)p_p^+ = 0 \\
\Leftrightarrow\ & p_p^+ = \frac{2\sigma(2\alpha(y_0-\sigma) + (1-\gamma))}{1-\gamma-4\alpha\sigma\eta},
\end{aligned}$$

and

$$q_p^+ = \frac{(1-\gamma)(2\alpha(y_0-\sigma) + (1-\gamma))}{2\alpha(1-\gamma-4\alpha\sigma\eta)},$$

and from Equation (A.54), we obtain

$$\begin{aligned}
f_p^+ =& -\alpha(q_p^+)^2 + h^+(q_p^+)(1-\gamma)p_p^+ \\
=& \frac{(1-\gamma)^2(2\alpha(y_0-\sigma)+1-\gamma)(2\alpha(\sigma-4\sigma\eta-y_0)+1-\gamma)}{4\alpha(-4\alpha\sigma\eta+1-\gamma)}.
\end{aligned}$$

Therefore, the platform's utility is

$$\begin{aligned}
\Pi_p^+ =& h^+(q_p^+)\gamma p_p^+ + f_p^+ \\
=& \frac{(1-\gamma)(2\alpha(y_0-\sigma)+1-\gamma)(1-\gamma^2+2\alpha\gamma(y_0-\sigma)+2\alpha(\sigma-4\sigma\eta-y))}{4\alpha(-4\alpha\sigma\eta+1-\gamma)^2}.
\end{aligned}$$

Moreover, since dispute fee has to be non-negative for contracting to occur, if $\sigma > y_0$, $f_p^+ = 0$ at $\alpha = \frac{1-\gamma}{2(\sigma-y_0)}$. If $\sigma \le y$, $f_p^+ = 0$ at $\alpha = \frac{1-\gamma}{2(y_0-\sigma+4\sigma\eta)}$. Therefore, if dispute occurs, there exists a threshold, $\hat{\alpha}_d$, such that $f_p^+ \ge 0$ if and only if $\alpha \le \hat{\alpha}_{dp}$, where $\hat{\alpha}_{dp}$ is given by

$$\hat{\alpha}_{dp} = \begin{cases} \frac{1-\gamma}{2(y_0-\sigma+4\sigma\eta)} & \text{if } \sigma \le y_0 \\ \frac{1-\gamma}{2(\sigma-y_0)} & \text{if } \sigma > y_0. \end{cases}$$

If $\alpha > \hat{\alpha}_{dp}$, since the dispute fee has to be non-negative, setting $f_p^+ = 0$ would cause the individual rationality constraint of the freelancer to be violated. We define $\bar{\alpha}_{dp} = \max(\underline{\alpha}_{dp}, \hat{\alpha}_{dp})$. Contracting occurs if and only if $\alpha \leq \bar{\alpha}_{dp}$. Thus, given that contracting occurs, dispute occurs in equilibrium if and only if $\underline{\alpha}_{dp} < \alpha \leq \bar{\alpha}_{dp}$. □

*Proof of Theorem 1.6* Following Propositions 1.5 and 1.6, we compare the platform's equilibrium utilities under the centralized and decentralized dispute systems. We first compare the $\alpha$ thresholds under the different dispute systems. Since the $\alpha$ thresholds under the different dispute systems are similar to those in the main model, following the proof of Theorem 1.1, we obtain that $\underline{\alpha}_{dp} \leq \underline{\alpha}_{cp}$ and $\bar{\alpha}_{dp} \leq \bar{\alpha}_{cp}$. Thus, we next compare the platform's equilibrium utilities between the centralized and decentralized dispute systems under three different cases.

(a) If $\alpha \leq \underline{\alpha}_{dp}$, dispute does not occur under either system. In this case, under the centralized dispute system, $\Pi_p^* = \frac{4\gamma\sigma\theta(y_0+\sigma)}{\gamma+4\sigma\theta(1-\eta)}$; under the decentralized dispute system, $\Pi_p^+ = \frac{\gamma(y_0+\sigma)}{1-\eta}$. Therefore, it is easy to see that $\Pi_p^+ \geq \Pi_p^*$ since $\frac{4\sigma\theta}{\gamma+4\sigma\theta} \leq 1$.

(b) If $\underline{\alpha}_{dp} < \alpha \leq \underline{\alpha}_{cp}$, we first check if $\bar{\alpha}_{dp} \leq \underline{\alpha}_{cp}$. Under $\sigma \leq \bar{\sigma}_p$, where $\bar{\sigma}_p = \frac{\sqrt{\gamma^2(1-4\eta)^2+4\gamma\theta(2\eta(4\eta-7)+5)y_0+4\theta^2(1-2\eta)^2y_0^2}+\gamma(4\eta-1)+2\theta(1-2\eta)y_0}{4\theta(2\eta(4\eta-5)+3)}$, we have

$$
\begin{aligned}
\underline{\alpha}_{cp} - \bar{\alpha}_{dp} &= \frac{1}{4}(1-\gamma)\left(\frac{\gamma - 4\sigma\theta\eta + 4\sigma\theta}{\sigma^2\theta + \sigma\theta y_0} + \frac{2}{-4\sigma\eta + \sigma - y_0}\right) \\
&\geq 0,
\end{aligned}
$$

where the last step follows from $\sigma \leq \frac{\sqrt{\gamma^2(1-4\eta)^2+4\gamma\theta(2\eta(4\eta-7)+5)y_0+4\theta^2(1-2\eta)^2y_0^2}+\gamma(4\eta-1)+2\theta(1-2\eta)y_0}{4\theta(2\eta(4\eta-5)+3)}$. Recall that since dispute occurs under the decentralized dispute system, $\Pi_p^+ = h^+(q_p^+)\gamma p_p^+ + f_p^+ = \gamma q_p^+ + f_p^+$. Thus, it is sufficient to compare $q_p^+$ with $q_p^*$ in order to compare between $\Pi_p^+$ and $\Pi_p^*$ since $\Pi_p^* = \gamma p_p^* = \gamma q_p^*$. Taking the difference of the two quality levels, we have

$$
q_p^+ - q_p^* = \frac{(1-\gamma)(2\alpha(\sigma - y_0) + \gamma - 1)}{2\alpha(4\alpha\sigma\eta + \gamma - 1)} - \frac{4\sigma\theta(\sigma + y_0)}{\gamma - 4\sigma\theta(\eta - 1)}.
$$

Since $\frac{\partial}{\partial\alpha}(q_p^+ - q_p^*) = \frac{(\gamma-1)\left(\gamma(8\alpha\sigma\eta-2)+8\alpha\sigma\eta(\alpha(\sigma-y_0)-1)+\gamma^2+1\right)}{2\alpha^2(4\alpha\sigma\eta+\gamma-1)^2} < 0$, $q_p^+ - q_p^*$ is the most negative at $\underline{\alpha}_{cp}$. At $\alpha = \underline{\alpha}_{cp}$, the difference $q_p^+ - q_p^*$ becomes

$$q_p^+ - q_p^* = \frac{\theta(\sigma + y_0)(\gamma(-4\sigma\eta + \sigma - y_0) + 2\sigma\theta(2\eta - 1)(\sigma(4\eta - 3) + y_0))}{(\gamma - 4\sigma\theta(\eta - 1))\left(\gamma\eta - \theta\left(\sigma(1 - 2\eta)^2 + y_0\right)\right)},$$

which is positive if $\sigma \leq \frac{\sqrt{\gamma^2(1-4\eta)^2+4\gamma\theta(2\eta(4\eta-7)+5)y_0+4\theta^2(1-2\eta)^2y_0^2}+\gamma(4\eta-1)+2\theta(1-2\eta)y_0}{4\theta(2\eta(4\eta-5)+3)}$. Therefore, since $q_p^+ \geq q_p^*$, $\Pi_p^+ \geq \Pi_p^*$ if $\alpha \leq \bar{\alpha}_{dp}$. Recall from Proposition 1.6 that $\bar{\alpha}_{dp} = \max(\frac{(1-\gamma)(1-\eta)}{y_0+\sigma}, \frac{1-\gamma}{2(y_0-\sigma+4\sigma\eta)})$. Thus, we can alternatively express the condition $\alpha \leq \bar{\alpha}_{dp}$ as $\eta \leq \bar{\eta}$, where $\bar{\eta} = \max(\frac{1-\gamma-\alpha(y_0+\sigma)}{1-\gamma}, \frac{1-\gamma-2\alpha(y_0-\sigma)}{8\alpha\sigma})$. We now derive some properties with regards to $\bar{\eta}$. If $\bar{\eta} = \frac{1-\gamma-\alpha(y_0+\sigma)}{1-\gamma}$, we have $\frac{\partial\bar{\eta}}{\partial\alpha} = -\frac{y_0+\sigma}{1-\gamma} < 0$. If $\bar{\eta} = \frac{1-\gamma-2\alpha(y_0-\sigma)}{8\alpha\sigma}$, we have $\frac{\partial\bar{\eta}}{\partial\alpha} = -\frac{1-\gamma}{8\alpha^2\sigma} < 0$. Therefore, $\bar{\eta}$ is decreasing in $\alpha$. □

## A.8 Proofs of Section 1.9.3 (Double-Sided Dispute Fees)

*Proof of Proposition 1.7* Proposition 1.7 can be proven by backward induction based on the decision tree in Figure 1.5.

At Stage 7, the platform makes the decision on the dispute, which will only occur if the client has rejected the freelancer's work and the freelancer has initiated the dispute. If the client does not pay the dispute fee, the freelancer wins by default. If the client pays the dispute fee, the platform makes a decision on the dispute, and the freelancer wins with probability $h^*(q)$.

At Stage 6, the client makes the decision on whether to pay the dispute fee, which will only occur if the client has previously rejected the freelancer's work and the freelancer has initiated the dispute. Thus, the client's utility is

$$U_c(p) = \begin{cases} q - h^*(q)p - f & \text{if client pays the dispute fee,} \\ q - p & \text{if client does not pay the dispute fee.} \end{cases}$$

As such, the client pays the dispute fee if $-h^*(q)p - f > p$, which can be rearranged as $(1 - h^*(q))p > f$, and does not pay the dispute fee otherwise.

At Stage 5, the freelancer makes the decision on whether to initiate the dispute, which will only occur if the client has rejected the freelancer's work. The freelancer's utility is

$$U_f(q) = \begin{cases} -\alpha q^2 + h^*(q)(1-\gamma)p - f & \text{if freelancer initiates dispute and } (1-h^*(q))p > f, \\ -\alpha q^2 + (1-\gamma)p - f & \text{if freelancer initiates dispute and } (1-h^*(q))p \le f, \\ -\alpha q^2 & \text{if freelancer does not initiate dispute.} \end{cases}$$

Therefore, the freelancer initiates the dispute if $f \ge (1-h^*(q))p$ and $(1-\gamma)p-f \ge 0$, or if $f < (1-h^*(q))p$ and $h^*(q)(1-\gamma)p - f \ge 0$. He does not initiate the dispute otherwise.

At Stage 4, the client decides whether to accept or reject the freelancer's work. If the client accepts the freelancer's work, her utility is

$$U_c = q - p.$$

If the client rejects the freelancer's work, her utility is

$$U_c(p) = \begin{cases} q - p & \text{if } f \ge (1-h^*(q))p \text{ and } (1-\gamma)p - f \ge 0, \\ q - h^*(q)p - f & \text{if } f < (1-h^*(q))p \text{ and } h^*(q)(1-\gamma)p - f \ge 0, \\ q & \text{otherwise.} \end{cases}$$

Therefore, the client accepts if $f \ge (1-h^*(q))p$ and $(1-\gamma)p - f \ge 0$, and rejects otherwise.

At Stage 3, the freelancer decides whether to participate or not and chooses his quality level if he participates. Given that the freelancer participates, his utility is given by

$$U_f(q) = \begin{cases} -\alpha q^2 + (1-\gamma)p & \text{if } f \ge (1-h^*(q))p \text{ and } (1-\gamma)p - f \ge 0, \\ -\alpha q^2 + h^*(q)(1-\gamma)p - f & \text{if } f < (1-h^*(q))p \text{ and } h^*(q)(1-\gamma)p - f \ge 0, \\ -\alpha q^2 & \text{otherwise.} \end{cases}$$

If $f \geq (1 - h^*(q))p$, the freelancer's utility is $-\alpha q^2 + (1-\gamma)p$, which is decreasing in $q$, and hence his optimal quality level is

$$(1 - h^*(q))p - f = 0$$
$$\Leftrightarrow q_d^* = y + \sigma - \frac{2\sigma f}{p} - \frac{\gamma p}{4\sigma\theta} \tag{A.55}$$

where the last step follows from $h^*(q) = \frac{q-y+\sigma}{2\sigma} + \frac{\gamma p}{8\theta\sigma^2}$. Therefore, the freelancer's utility is $U_{f,1} = -\alpha(y+\sigma-\frac{2\sigma f}{p} - \frac{\gamma p}{4\sigma\theta})^2 + (1-\gamma)p$. If $f < (1-h^*(q))p$, the freelancer's utility is $-\alpha q^2 + h^*(q)(1-\gamma)p - f$ and his optimal quality level is

$$q_d^* = \frac{(1-\gamma)p}{4\sigma\alpha}. \tag{A.56}$$

Therefore, the freelancer's utility is $U_{f,2} = -\alpha(\frac{(1-\gamma)p}{4\sigma\alpha})^2 + h^*(\frac{(1-\gamma)p}{4\sigma\alpha})(1-\gamma)p - f$. Hence, following the proof of Proposition 1.1, the freelancer's optimal quality level is

$$q_d^* = \begin{cases} y + \sigma - \frac{2\sigma f}{p} - \frac{\gamma p}{4\sigma\theta} & \text{if } \alpha \leq \underline{\alpha}_{cd}, \\ \frac{(1-\gamma)p}{4\sigma\alpha} & \text{if } \alpha > \underline{\alpha}_{cd}, \end{cases}$$

where $\underline{\alpha}_{cd}$ is the $\alpha$ threshold such that $U_{f,1} = U_{f,2}$ when the dispute fee is double-sided.

At Stage 2, the client decides whether to participate or not and if she participates, she chooses the price to offer to the freelancer, subject to the freelancer's individual rationality constraint.

(a) If $\alpha \leq \underline{\alpha}_{cd}$ and $(1-\gamma)p - f \geq 0$, dispute does not occur and $q_d^* = y + \sigma - \frac{2\sigma f}{p} - \frac{\gamma p}{4\sigma\theta}$. Thus, the client's problem is

$$\max_{p \geq 0} \quad q_d^* - p,$$
$$\text{s.t.} \quad -\alpha(q_d^*)^2 + (1-\gamma)p \geq 0.$$

Since the client's utility is decreasing in $p$, $p$ is chosen such that $(1-\gamma)p - f \geq 0$ and $-\alpha(q_d^*)^2 + (1-\gamma)p \geq 0$ for the freelancer to participate. Therefore, $p_d^* = \max(\frac{\alpha(q_d^*)^2}{1-\gamma}, \frac{f}{1-\gamma})$.

(b) If $\alpha > \underline{\alpha}_{cd}$ and $h^*(q_d^*)(1-\gamma)p - f \geq 0$, dispute occurs and $q_d^* = \frac{(1-\gamma)p}{4\sigma\alpha}$. The client's problem is

$$\begin{aligned}
\max_{p \geq 0} \quad & q_d^* - h^*(q_d^*)p - f, \\
\text{s.t.} \quad & -\alpha(q_d^*)^2 + h^*(q_d^*)(1-\gamma)p - f \geq 0.
\end{aligned}$$

Notice that under this scenario, since the client's expected utility is of a similar form as our main model, the analysis for the client's optimal $p_d^*$ follows from the proof of Proposition 1.1.

At Stage 1, the platform chooses the dispute fee $f$ while satisfying the individual rationality constraints of the client and the freelancer.

(a) Recall from previous analyses that if $\alpha \leq \underline{\alpha}_{cd}$, dispute does not occur. The client offers price $p_d^* = \max(\frac{\alpha(q_d^*)^2}{1-\gamma}, \frac{f}{1-\gamma})$ and the freelancer chooses quality $q_d^* = y + \sigma - \frac{2\sigma f}{p_d^*} - \frac{\gamma p_d^*}{4\sigma\theta}$. Thus, the platform will achieve utility $\Pi = \gamma p_d^*$. Thus, the platform's problem is as follows:

$$\begin{aligned}
\max_{f \geq 0} \quad & \gamma \max\left(\frac{\alpha(q_d^*)^2}{1-\gamma}, \frac{f}{1-\gamma}\right), \\
\text{s.t.} \quad & q_d^* - \max\left(\frac{\alpha(q_d^*)^2}{1-\gamma}, \frac{f}{1-\gamma}\right) \geq 0, \\
& -\alpha(q_d^*)^2 + (1-\gamma)\max\left(\frac{\alpha(q_d^*)^2}{1-\gamma}, \frac{f}{1-\gamma}\right) \geq 0.
\end{aligned}$$

Notice that this is similar to the platform's problem in solving for the optimal dispute fee under the centralized dispute system in the main model. Thus, we have $f_d^* = (1-\gamma)p_d^*$ and $p_d^* = q_d^*$. Therefore, from Equation (A.55), $q_f^*$ is given by

$$\begin{aligned}
q_d^* &= y + \sigma - \frac{2(1-\gamma)\sigma q_d^*}{q_d^*} - \frac{\gamma q_d^*}{4\theta\sigma^2} \\
\Leftrightarrow q_d^* &= \frac{4\sigma\theta(y + \sigma - 2(1-\gamma)\sigma)}{\gamma + 4\sigma\theta}.
\end{aligned}$$

Moreover, from the individual rationality constraint of the freelancer, we obtain

$\underline{\alpha}_{cd} = \frac{(1-\gamma)(\gamma+4\sigma\theta)}{4\sigma\theta(y+\sigma-2(1-\gamma)\sigma)}$. Therefore, if $\alpha \leq \underline{\alpha}_{cd}$, the platform's equilibrium utility is

$$\Pi_d^* = \gamma \frac{4\sigma\theta(y + \sigma - 2(1-\gamma)\sigma)}{\gamma + 4\sigma\theta}.$$

(b) Recall from previous analyses that if $\alpha > \underline{\alpha}_{cd}$ and $h^*(q_d^*)(1-\gamma)p_d^* - f \geq 0$, dispute is initiated by the freelancer and the client pays the dispute fee. The platform's problem is

$$\max_{f\geq 0} \quad h^*(q_d^*)\gamma p_d^* + 2f - \frac{\gamma^2 (p_d^*)^2}{16\theta\sigma^2},$$

$$\text{s.t.} \quad q_d^* - h^*(q_d^*)p_d^* - f \geq 0, \tag{A.57}$$

$$-\alpha(q_d^*)^2 + h^*(q_d^*)(1-\gamma)p_d^* - f \geq 0. \tag{A.58}$$

where Equation (A.57) is the individual rationality constraint of the client, and Equation (A.58) is the individual rationality constraint of the freelancer. Notice that the analysis for the equilibrium outcome follows the proof of Proposition 1.1. Thus, the platform's expected utility is increasing in $f$ and the platform chooses the optimal $f$ such that both Equations (A.57) and (A.58) are binding, resulting in

$$-\alpha(q_d^*)^2 + h^*(q_d^*)(1-\gamma)p_d^* - q_d^* + h^*(q_d^*)p_d^* = 0.$$

Substituting Equation (A.56) and $h(q_d^*) = \frac{q_d^* - y + \sigma}{2\sigma} + \frac{\gamma p_d^*}{8\theta\sigma^2}$ into the above equation, we have

$$p_d^* = \frac{4\sigma\theta(2(2-\gamma)\alpha(y-\sigma) + (1-\gamma))}{(3-\gamma)(1-\gamma)\theta + 2(2-\gamma)\gamma\alpha}. \tag{A.59}$$

Consequently, substituting Equation (A.59) into Equation (A.56), we have

$$q_d^* = \frac{(1-\gamma)\theta(2(2-\gamma)\alpha(y-\sigma) + (1-\gamma))}{\alpha((3-\gamma)(1-\gamma)\theta + 2(2-\gamma)\gamma\alpha)},$$

and from the binding Equation (A.57), we have

$$f_d^* = \frac{(1-\gamma)^2\theta(2(2-\gamma)\alpha(y-\sigma) + (1-\gamma))(2\alpha(\gamma - \theta(y-\sigma)) + (1-\gamma)\theta)}{\alpha((3-\gamma)(1-\gamma)\theta + 2(2-\gamma)\gamma\alpha)^2}.$$

The platform's expected utility is then

$$
\begin{aligned}
\Pi_d^* =& h^*(q_d^*)\gamma p_d^* + 2f_d^* - \frac{\gamma^2(p_d^*)^2}{16\theta\sigma^2} \\
=& \frac{\theta(2(2-\gamma)\alpha(y-\sigma)+(1-\gamma))}{\alpha((3-\gamma)(1-\gamma)\theta+2(2-\gamma)\gamma\alpha)^2}\Big((-2\alpha^2(2-\gamma)\gamma^2(y-\sigma) \\
&+\alpha(1-\gamma)(\gamma(4-3\gamma)-2(3-\gamma)\gamma\sigma\theta-2(2-\gamma)(1-\gamma)\theta y+4\sigma\theta)+2(1-\gamma)^2\theta\Big).
\end{aligned}
$$

Moreover, since dispute fee has to be non-negative for contracting to occur, if $\sigma > y$, $f_d^* = 0$ at $\alpha = \frac{(1-\gamma)\theta}{2(2-\gamma)(\sigma-y)}$. If $\sigma \le y - \frac{\gamma}{\theta}$, $f_d^* = 0$ at $\alpha = \frac{(1-\gamma)\theta}{2(\theta(y-\sigma)-\gamma)}$. If $y - \frac{\gamma}{\theta} < \sigma \le y$, $f_d^* \ge 0$ for all $\alpha$. Therefore, if dispute occurs, there exists a threshold, $\hat{\alpha}_{cd}$, such that $f_d^* \ge 0$ if and only if $\alpha \le \hat{\alpha}_{cd}$, where $\hat{\alpha}_{cd}$ is given by

$$
\hat{\alpha}_{cd} = \begin{cases} \frac{(1-\gamma)\theta}{2(\theta(y-\sigma)-\gamma)} & \text{if } \sigma \le y - \frac{\gamma}{\theta}, \\ \infty & \text{if } y - \frac{\gamma}{\theta} < \sigma \le y. \\ \frac{(1-\gamma)\theta}{2(2-\gamma)(\sigma-y)} & \text{if } \sigma > y. \end{cases}
$$

If $\alpha > \hat{\alpha}_{cd}$, since the dispute fee has to be non-negative, setting $f_d^* = 0$ would cause the individual rationality constraint of the freelancer to be violated. We define $\bar{\alpha}_{cd} = \max(\underline{\alpha}_{cd}, \hat{\alpha}_{cd})$. Contracting occurs if and only if $\alpha \le \bar{\alpha}_{cd}$. Thus, given that contracting occurs, dispute occurs in equilibrium if and only if $\underline{\alpha}_{cd} < \alpha \le \bar{\alpha}_{cd}$.

Finally, we compare the thresholds to the main model under $\sigma \le y$. Comparing $\underline{\alpha}_{cd}$ with $\underline{\alpha}_c$, We have $\underline{\alpha}_{cd} - \underline{\alpha}_c = \frac{(1-\gamma)(\gamma+4\sigma\theta)}{4\sigma\theta}(\frac{1}{y+\sigma-2(1-\gamma)\sigma} - \frac{1}{y+\sigma}) \ge 0$ and thus, $\underline{\alpha}_{cd} \ge \underline{\alpha}_c$. Comparing $\bar{\alpha}_{cd}$ with $\bar{\alpha}_c$, since $\hat{\alpha}_{cd} = \hat{\alpha}_c$ if $\sigma \le y$, we have $\bar{\alpha}_{cd} = \max(\underline{\alpha}_{cd}, \hat{\alpha}_c) \ge \max(\underline{\alpha}_c, \hat{\alpha}_c) = \bar{\alpha}_c$. □

*Proof of Proposition 1.8* Proposition 1.8 can be proven by backward induction based on the decision tree in Figure 1.5.

At Stage 7, the dispute decision is made, which will only occur if the client has rejected the freelancer's work and the freelancer has initiated the dispute.

If the client does not pay the dispute fee, the freelancer wins by default. If the client pays the dispute fee, the tribunal makes a decision on the dispute, and the freelancer wins with probability $h^+(q)$.

At Stage 6, the client makes the decision on whether to pay the dispute fee, which will only occur if the client has rejected the freelancer's work and the freelancer has initiated the dispute. Therefore, the client's utility is

$$U_c(p) = \begin{cases} q - h^+(q)p - f & \text{if client pays the dispute fee,} \\ q - p & \text{if client does not pays the dispute fee.} \end{cases}$$

As such, the client pays the dispute fee if $-h^+(q)p - f > -p$, which simplifies to $f < (1 - h^+(q))p$, and does not pay the dispute fee otherwise.

At Stage 5, the freelancer makes the decision on whether to initiate the dispute, which will only occur if the client has rejected the freelancer's work. The freelancer's utility is

$$U_f(q) = \begin{cases} -\alpha q^2 + (1-\gamma)p - f & \text{if } f \geq (1 - h^+(q))p \text{ and initiates dispute,} \\ -\alpha q^2 + h^+(q)(1-\gamma)p - f & \text{if } f < (1 - h^+(q))p \text{ and initiates dispute,} \\ -\alpha q^2 & \text{if dispute is not initiated.} \end{cases}$$

Therefore, the freelancer initiates the dispute if $f \geq (1-h^+(q))p$ and $(1-\gamma)p-f \geq 0$, or if $f < (1 - h^+(q))p$ and $h^+(q)(1 - \gamma)p - f \geq 0$. He does not initiate the dispute otherwise.

At Stage 4, the client decides whether to accept or reject the freelancer's work. If the client accepts the freelancer's work, her utility is

$$U_c(p) = q - p.$$

If the client rejects the freelancer's work, her utility is

$$U_c(p) = \begin{cases} q - p & \text{if } f \geq (1 - h^+(q))p \text{ and } (1-\gamma)p - f \geq 0, \\ q - h^+(q)p - f & \text{if } f < (1 - h^+(q))p \text{ and } h^+(q)(1-\gamma)p - f \geq 0, \\ q & \text{otherwise.} \end{cases}$$

Therefore, the client accepts if $f \geq (1 - h^+(q))p$ and $(1-\gamma)p - f \geq 0$, and rejects otherwise.

At Stage 3, the freelancer decides whether to participate or not and chooses his quality level if he participates. Given that the freelancer participates, his utility is given by

$$U_f(q) = \begin{cases} -\alpha q^2 + (1-\gamma)p & \text{if } f \geq (1 - h^+(q))p \text{ and } (1-\gamma)p - f \geq 0, \\ -\alpha q^2 + h^+(q)(1-\gamma)p - f & \text{if } f < (1 - h^+(q))p \text{ and } h^+(q)(1-\gamma)p - f \geq 0, \\ -\alpha q^2 & \text{otherwise.} \end{cases}$$

If $f \geq (1 - h^+(q))p$, the freelancer's utility is $-\alpha q^2 + (1-\gamma)p$, which is decreasing in $q$, and hence his optimal quality level is

$$\begin{aligned} q_d^+ &= h^{-1}(1 - \frac{f}{p}) \\ &= 2\sigma(1 - \frac{f}{p}) + y - \sigma. \end{aligned} \tag{A.60}$$

Therefore, the freelancer's utility is $U_{f,1} = -\alpha(2\sigma(1 - \frac{f}{p}) + y - \sigma)^2 + (1-\gamma)p$. If $f < (1 - h^+(q))p$, the freelancer's utility is $-\alpha q^2 + h^+(q)(1-\gamma)p - f$ and following from Proposition 1.3, his optimal quality level is

$$q_d^+ = \frac{(1-\gamma)p}{4\sigma\alpha}. \tag{A.61}$$

Therefore, the freelancer's utility is $U_{f,2} = -\alpha(\frac{(1-\gamma)p}{4\sigma\alpha})^2 + h^+(\frac{(1-\gamma)p}{4\sigma\alpha})(1-\gamma)p - f$. Hence, following the proof of Proposition 1.3, the freelancer's optimal quality level is

$$q_d^+ = \begin{cases} 2\sigma(1-\frac{f}{p}) + y - \sigma & \text{if } \alpha \leq \underline{\alpha}_{dd}, \\ \frac{(1-\gamma)p}{4\sigma\alpha} & \text{if } \alpha > \underline{\alpha}_{dd}, \end{cases}$$

where $\underline{\alpha}_{dd}$ is the $\alpha$ threshold such that $U_{f,1} = U_{f,2}$ when the dispute fee is double-sided.

At Stage 2, the client decides whether to participate or not and if she participates, she chooses the price to offer to the freelancer, subject to the freelancer's individual rationality constraint. Given that the client participates, her utility is given by

$$U_c(p) = \begin{cases} (2\sigma(1-\frac{f}{p}) + y - \sigma) - p & \text{if } \alpha \leq \underline{\alpha}_{dd} \text{ and } (1-\gamma)p - f \geq 0, \\ q_d^+ - h(q_d^+)p - f & \text{if } \alpha > \underline{\alpha}_{dd} \text{ and } h(q_d^+)(1-\gamma)p - f \geq 0. \end{cases}$$

(a) If $\alpha \leq \underline{\alpha}_{dd}$ and $(1-\gamma)p - f \geq 0$, $q_d^+ = 2\sigma(1-\frac{f}{p}) + y - \sigma$ and from Stage 4, the client accepts the freelancer's work. Thus, the client's problem is

$$\begin{aligned} \max_{p \geq 0} \quad & q_d^+ - p, \\ \text{s.t.} \quad & -\alpha(q_d^+)^2 + (1-\gamma)p \geq 0. \end{aligned}$$

Since the client's utility is decreasing in $p$, $p$ is chosen such that $(1-\gamma)p - f \geq 0$ and $-\alpha(q_d^+)^2 + (1-\gamma)p \geq 0$ for the freelancer to participate. Therefore, $p_d^+ = \max(\frac{\alpha(q_d^+)^2}{1-\gamma}, \frac{f}{1-\gamma})$.

(b) If $\alpha > \underline{\alpha}_{dd}$ and $h(q_d^+)(1-\gamma)p - f \geq 0$, $q_d^+ = \frac{h'(q_d^+)(1-\gamma)p}{2\alpha}$ and from Stage 4, the client rejects the freelancer's work. Thus, the client's problem is

$$\begin{aligned} \max_{p \geq 0} \quad & q_d^+ - h(q_d^+)p - f, \\ \text{s.t.} \quad & -\alpha(q_d^+)^2 + h(q_d^+)(1-\gamma)p - f \geq 0. \end{aligned}$$

Notice that under this scenario, the analysis for the client's optimal $p_d^+$ follows from the proof of Proposition 1.3.

At Stage 1, the platform chooses the dispute fee $f$ while satisfying the individual rationality constraints of the client and the freelancer.

(a) Recall from previous analyses that if $\alpha \le \underline{\alpha}_{dd}$, dispute does not occur. Moreover, we have $q_d^+ = 2\sigma(1 - \frac{f}{p_d^+}) + y - \sigma$ and $p_d^+ = \max(\frac{\alpha(q_d^+)^2}{1-\gamma}, \frac{f}{1-\gamma})$. Thus, the platform's problem is

$$\begin{aligned} \max_{f\ge 0} \quad & \gamma \max\left(\frac{\alpha(q_d^+)^2}{1-\gamma}, \frac{f}{1-\gamma}\right), \\ \text{s.t.} \quad & q_d^+ - \max\left(\frac{\alpha(q_d^+)^2}{1-\gamma}, \frac{f}{1-\gamma}\right) \ge 0, && \text{(A.62)} \\ & -\alpha(q_d^+)^2 + (1-\gamma)\max\left(\frac{\alpha(q_d^+)^2}{1-\gamma}, \frac{f}{1-\gamma}\right) \ge 0, && \text{(A.63)} \end{aligned}$$

where Equation (A.62) is the individual rationality constraint of the client, and Equation (A.63) is the individual rationality constraint of the freelancer. Notice that this is similar to the platform's problem in solving for the optimal dispute fee under the decentralized dispute system in the main model. Thus, as the platform's utility is increasing in $f$, it increases $f$ until the individual rationality constraint of the client is binding. Thus, $p_d^+ = \frac{f}{1-\gamma}$. From the binding Equation (A.62), we have

$$f_d^+ = (1-\gamma)(y - \sigma + 2\gamma\sigma),$$

and from $p_d^+ = \frac{f_d^+}{1-\gamma}$ we have,

$$p_d^+ = (y - \sigma + 2\gamma\sigma).$$

The condition $\alpha \le \underline{\alpha}_{dd}$ can then be simplified to $\alpha \le \frac{1-\gamma}{q_d^+} = \frac{1-\gamma}{y-\sigma+2\gamma\sigma} = \underline{\alpha}_{dd}$. Therefore, if $\alpha \le \underline{\alpha}_{dd}$, the platform's utility is

$$\Pi_d^+ = \gamma(y - \sigma + 2\gamma\sigma).$$

(b) Recall from previous analyses that if $\alpha > \underline{\alpha}_{dd}$ and $h(q_d^+)(1-\gamma)p - f \geq 0$, dispute is initiated by the freelancer and the client pays the dispute fee. The platform's problem is

$$\begin{aligned}
\max_{f\geq 0} \quad & h(q_d^+)\gamma p_d^+ + 2f \\
\text{s.t.} \quad & q_d^+ - h(q_d^+)p_d^+ - f \geq 0, && \text{(A.64)} \\
& -\alpha(q_d^+)^2 + h(q_d^+)(1-\gamma)p_d^+ - f \geq 0, && \text{(A.65)}
\end{aligned}$$

where Equation (A.64) is the individual rationality constraint of the client, and Equation (A.65) is the individual rationality constraint of the freelancer. Notice that the analysis for the equilibrium outcome follows the proof of Proposition 1.3. Thus, the platform's expected utility is increasing in $f$ and the platform chooses the optimal $f$ such that both Equations (A.64) and (A.65) are binding, resulting in

$$-\alpha(q_d^+)^2 + h(q_d^+)(1-\gamma)p_d^+ - q_d^+ + h(q_d^+)p_d^+ = 0.$$

Substituting Equation (A.61) and $h(q_d^+) = \frac{q_d^+ - y + \sigma}{2\sigma}$ into the above equation, we have

$$p_d^+ = \frac{4\sigma(2(2-\gamma)\alpha(y-\sigma)\gamma + (1-\gamma))}{\gamma^2 - 4\gamma + 3}. \tag{A.66}$$

Consequently, substituting Equation (A.66) into Equation (A.61), we have

$$q_d^+ = \frac{(1-\gamma)(2(2-\gamma)\alpha(y-\sigma)\gamma + (1-\gamma))}{\alpha(\gamma^2 - 4\gamma + 3)},$$

and from the binding Equation (A.64), we have

$$f_d^+ = \frac{(-2\alpha(y-\sigma) + (1-\gamma))(2(2-\gamma)\alpha(y-\sigma) - (1+\gamma))}{\alpha(3-\gamma)^2}. \tag{A.67}$$

The platform's expected utility is

$$\begin{aligned}
\Pi_d^+ &= h(q_d^+)\gamma p_d^+ + 2f_d^+ \\
&= \frac{2(-(2-\gamma)\alpha(y-\sigma)+)(2(2-\gamma)\alpha(y-\sigma) + (1-\gamma))}{\alpha(3-\gamma)^2}.
\end{aligned}$$

Moreover, since dispute fee has to be non-negative for contracting to occur, if $\sigma > y$, $f_d^+ = 0$ at $\alpha = \frac{1-\gamma}{2(2-\gamma)(\sigma-y)}$. If $\sigma \le y$, $f_d^+ = 0$ at $\alpha = \frac{1-\gamma}{2(y-\sigma)}$. Therefore, if dispute occurs, there exists a threshold $\hat{\alpha}_{dd}$, which is the solution of $f_d^+ = 0$, such that $f_d^+ \ge 0$ if and only if $\alpha \le \hat{\alpha}_{dd}$, where $\hat{\alpha}_{dd}$ is given by

$$\hat{\alpha}_{dd} = \begin{cases} \frac{1-\gamma}{2(y-\sigma)} & \text{if } \sigma \le y, \\ \frac{1-\gamma}{2(2-\gamma)(\sigma-y)} & \text{if } \sigma > y. \end{cases}$$

If $\alpha > \hat{\alpha}_{dd}$, since the dispute fee has to be non-negative, setting $f_d^+ = 0$ would cause the individual rationality constraint of the freelancer to be violated. We define $\bar{\alpha}_{dd} = \max(\underline{\alpha}_{dd}, \hat{\alpha}_{dd})$. Contracting occurs if and only if $\alpha \le \bar{\alpha}_{dd}$. Thus, given that contracting occurs, dispute occurs in equilibrium if and only if $\underline{\alpha}_{dd} < \alpha \le \bar{\alpha}_{dd}$.

Finally, we compare the thresholds to the main model under $\sigma \le y$. Comparing $\underline{\alpha}_{dd}$ with $\underline{\alpha}_d$, we have $\underline{\alpha}_{dd} - \underline{\alpha}_d = (1-\gamma)(\frac{1}{y+\sigma-2(1-\gamma)\sigma} - \frac{1}{y+\sigma}) \ge 0$ and thus, $\underline{\alpha}_{dd} \ge \underline{\alpha}_d$. Comparing $\bar{\alpha}_{dd}$ with $\bar{\alpha}_d$, since $\hat{\alpha}_{dd} = \hat{\alpha}_d$ if $\sigma \le y$, we have $\bar{\alpha}_{dd} = \max(\underline{\alpha}_{dd}, \hat{\alpha}_d) \ge \max(\underline{\alpha}_d, \hat{\alpha}_d) = \bar{\alpha}_d$. □

*Proof of Theorem 1.7* Let $\Pi_d^*$ be the platform's equilibrium utility under the centralized dispute system with double-sided dispute fees, and $\Pi^*$ be the platform's equilibrium utility under the centralized dispute system with a single-sided dispute fee. Similarly, let $\Pi_d^+$ be the platform's equilibrium utility under the decentralized dispute system with double-sided dispute fees, and $\Pi^+$ be the platform's equilibrium utility under the decentralized dispute system with a single-sided dispute fee.

First, we compare the equilibrium utilities under the decentralized dispute system with a single-sided dispute fee and the centralized dispute system with double-sided dispute fees. Recall that $\underline{\alpha}_{cd} - \underline{\alpha}_d \ge 0$. Thus, there is no dispute over a greater range of $\alpha$ under the centralized dispute system. If dispute does not occur under both systems (i.e., $\alpha \leq \underline{\alpha}_d$), the difference $\Pi^+ - \Pi_d^*$ is given by

$$\begin{aligned}\Pi^+ - \Pi_d^* &= \gamma(y+\sigma) - \gamma\frac{4\sigma\theta(y+\sigma-2(1-\gamma)\sigma)}{\gamma+4\sigma\theta}\\ &\geq \gamma(y+\sigma) - \gamma\frac{4\sigma\theta(y+\sigma)}{\gamma+4\sigma\theta}\\ &> 0,\end{aligned}$$

where the last step follows from $\gamma > 0$ and $\theta > 0$. If dispute does not occur under the centralized dispute system with double-sided dispute fees and occurs under the decentralized dispute system with single-sided dispute fees (i.e., $\underline{\alpha}_d < \alpha \leq \underline{\alpha}_{cd}$), the difference $q_d^+ - q_d^*$ is given by

$$\begin{aligned}q^+ - q_d^* &= \frac{1-\gamma}{2\alpha} + y - \sigma - \frac{4\sigma\theta(y+\sigma-2(1-\gamma)\sigma)}{\gamma+4\sigma\theta}\\ &\geq \frac{1-\gamma}{2\alpha} + y - \sigma - \frac{4\sigma\theta(y+\sigma)}{\gamma+4\sigma\theta}\\ &\geq 0,\end{aligned}$$

where the last step follows from $\sigma \leq \bar{\sigma}$. Moreover, we note that if $\sigma \leq \bar{\sigma}$, $\bar{\alpha}_d \leq \underline{\alpha}_c \leq \underline{\alpha}_{cd}$. Therefore, since $\Pi^+ = \gamma q^+ + f^+$ and $\Pi_d^* = \gamma q_d^*$, $\Pi^+ \geq \Pi_d^*$ if and only if $\alpha \leq \bar{\alpha}_d$.

Second, we compare the equilibrium utilities under the decentralized dispute system with double-sided dispute fees and under the decentralized dispute system with a single-sided dispute fee. Note that $\underline{\alpha}_{dd} - \underline{\alpha}_d = \frac{1-\gamma}{y-\sigma+2\gamma\sigma} - \frac{1-\gamma}{y+\sigma} \geq 0$. If dispute does not occur (i.e., $\alpha \leq \underline{\alpha}_d$), the difference $\Pi^+ - \Pi_d^+$ is given by

$$\begin{aligned}\Pi^+ - \Pi_d^+ &= \gamma(y+\sigma) - \gamma(y-\sigma+2\gamma\sigma)\\ &= 2\gamma(1-\gamma)\sigma\\ &\geq 0.\end{aligned}$$

If dispute does not occur under the decentralized dispute system with double-sided dispute fees and occurs under the decentralized dispute system with single-sided dispute fee (i.e., $\underline{\alpha}_d < \alpha \leq \underline{\alpha}_{dd}$), the difference $q^+ - q_d^+$ is given by

$$\begin{aligned} q^+ - q_d^+ &= \frac{1-\gamma}{2\alpha} + y - \sigma - (y - \sigma + 2\gamma\sigma) \\ &\geq 0, \end{aligned}$$

if $\alpha \leq \frac{1-\gamma}{4\sigma\gamma}$. Comparing this $\alpha$ threshold with $\underline{\alpha}_d$, we have

$$\begin{aligned} \frac{1-\gamma}{4\sigma\gamma} - \underline{\alpha}_d &= \frac{1-\gamma}{4\sigma\gamma} - \frac{1-\gamma}{y+\sigma} \\ &= \frac{(1-\gamma)(y + (1-4\gamma)\sigma)}{4\sigma\gamma(y+\sigma)} \\ &\geq \frac{(1-\gamma)(y - \frac{1}{3}\sigma)}{4\sigma\gamma(y+\sigma)} \\ &\geq 0, \end{aligned}$$

where the third step follows from $\gamma \leq \frac{1}{3}$ and the last step follows from $\sigma \leq \bar{\sigma}$. Therefore, $q^+ - q_d^+ \geq 0$ and $\Pi^+ - \Pi_d^+ = \gamma q^+ + f^+ - \gamma q_d^+ \geq 0$ if dispute only occurs under the decentralized dispute system with single-sided dispute fee. Moreover, recall from the proof of Theorem 1.2 that dispute does not occur under the decentralized dispute system with single-sided dispute fee if $\sigma \leq \frac{y}{3}$. In this case, $\bar{\alpha}_d = \underline{\alpha}_d$ and we have $\Pi_d^+ \geq \Pi^+$ if $\alpha > \bar{\alpha}_d$.

If dispute occurs under decentralized dispute system with double-sided fees (i.e., $\underline{\alpha}_{dd} < \bar{\alpha}_{dd}$, which implies that $\frac{y}{1+2\gamma} < \sigma \leq y$), dispute will also occur under decentralized dispute system with a single-sided fee since $\frac{y}{3} \leq \frac{y}{1+2\gamma} < \sigma$. Furthermore, in this case, $\bar{\alpha}_{dd} = \bar{\alpha}_d = \frac{1-\gamma}{2(y-\sigma)}$. Thus, if dispute occurs under both systems (i.e., $\underline{\alpha}_{dd} < \alpha$), the difference $\Pi^+ - \Pi_d^+$ is given by

$$\Pi^+ - \Pi_d^+ = \frac{-(1-\gamma)(-2\alpha(y-\sigma) + (1-\gamma))(2(7-3\gamma)\alpha(y-\sigma) + ((\gamma-4)\gamma - 1))}{4\alpha(3-\gamma)^2}. \tag{A.68}$$

Since $\alpha \leq \bar{\alpha}_d = \frac{1-\gamma}{2(y+\sigma)}$, $(1 - \gamma - 2\alpha(y - \sigma)) \geq 0$ and so Equation (A.68) is negative only if $(2\alpha(7-3\gamma)(y-\sigma) + ((\gamma-4)\gamma - 1)) \geq 0$. Thus, $\Pi^+ - \Pi_d^+ \geq 0$ if $\alpha \geq \frac{(1-4\gamma-\gamma^2)}{2(7-3\gamma)(y-\sigma)}$.

Moreover, $\frac{1-\gamma}{2(y-\sigma)} - \frac{(1-4\gamma-\gamma^2)}{2(7-3\gamma)(y-\sigma)} = \frac{3(1-\gamma)+2\gamma^2}{(7-3\gamma)(y-\sigma)} \geq 0$ for $\gamma \leq \frac{1}{3}$ and $\sigma \leq y$. Therefore, $\Pi_d^+ \geq \Pi^+$ if $\max(\underline{\alpha}_{dd}, \frac{(1-4\gamma-\gamma^2)}{2(7-3\gamma)(y-\sigma)}) \leq \alpha \leq \frac{1-\gamma}{2(y-\sigma)}$, which can be equivalently expressed as $\max(\underline{\alpha}_{dd}, \frac{(1-4\gamma-\gamma^2)}{2(7-3\gamma)(y-\sigma)}) \leq \alpha \leq \bar{\alpha}_d$ for $\sigma > \frac{y}{3}$. Furthermore, since $\Pi^+$ is always greater than $\Pi_d^*$ and $\Pi^*$, $\Pi_d^+$ will also be greater than $\Pi_d^*$ and $\Pi^*$ in this case.

Third, we compare the equilibrium utilities under the decentralized dispute system with double-sided dispute fees and under the centralized dispute system with a single-sided dispute fee. If dispute does not occur under both systems, (i.e., $\alpha \leq \min(\underline{\alpha}_{dd}, \underline{\alpha}_c)$), the difference $\Pi_d^+ - \Pi^*$ is given by

$$\Pi_d^+ - \Pi^* = \gamma(y + \sigma - 2(1-\gamma)\sigma) - \gamma\frac{4\sigma\theta(y+\sigma)}{\gamma + 4\sigma\theta},$$

which is positive if $\sigma \leq \frac{\sqrt{(1-2\gamma)^2\gamma^2+32(1-\gamma)\gamma\theta y}-(1-2\gamma)\gamma}{16(1-\gamma)\theta}$ since the other root of $\Pi_d^+ - \Pi^* = 0$ is negative. Note that as $\theta \to 0$, $\frac{\sqrt{(1-2\gamma)^2\gamma^2+32(1-\gamma)\gamma\theta y}-(1-2\gamma)\gamma}{16(1-\gamma)\theta} \to \infty$ and thus, $\frac{\sqrt{(1-2\gamma)^2\gamma^2+32(1-\gamma)\gamma\theta y}-(1-2\gamma)\gamma}{16(1-\gamma)\theta}$ can be greater than $\bar{\sigma}$.

If dispute occurs under the decentralized dispute system with double-sided dispute fees and does not occur under the centralized dispute system with a single-sided dispute fee (i.e., $\underline{\alpha}_{dd} < \alpha \leq \underline{\alpha}_c$), the difference $q_d^+ - q^*$ is given by

$$q_d^+ - q^* = \frac{(1-\gamma)(2(2-\gamma)\alpha(y-\sigma)\gamma + (1-\gamma))}{\alpha(\gamma^2 - 4\gamma + 3)} - \frac{4\sigma\theta(y+\sigma)}{\gamma + 4\sigma\theta}.$$

and is decreasing in $\alpha$ as $\frac{\partial}{\partial\alpha}(q_d^+ - q^*) = -\frac{1-\gamma}{\alpha^2(3-\gamma)} < 0$. At $\underline{\alpha}_c$, the difference becomes

$$q_d^+ - q^* = \frac{2(2-\gamma)(\gamma(y-\sigma) + 2\sigma\theta(y-3\sigma))}{(3-\gamma)(\gamma+4\sigma\theta)},$$

which is positive if $\sigma \leq \bar{\sigma}$. Moreover, if dispute occurs, $\bar{\alpha}_{dd} = \frac{1-\gamma}{2(y-\sigma)} = \bar{\alpha}_d$ and we know that $\frac{1-\gamma}{2(y-\sigma)} \leq \frac{(1-\gamma)(\gamma+4\sigma\theta)}{4\sigma\theta(y+\sigma)} = \underline{\alpha}_c$ from Theorem 1.2. Therefore, if $\sigma \leq \bar{\sigma}$, $q_d^+ \geq q^*$ and $\Pi_d^+ - \Pi^* = \gamma q_d^+ + 2f_d^+ - \gamma q^* \geq 0$ if $\underline{\alpha}_{dd} < \alpha \leq \bar{\alpha}_d$.

Finally, since the decentralized dispute system only occurs under the scenario where dispute does not occur under the centralized dispute systems if $\sigma \leq \bar{\sigma}$, we only need to compare the equilibrium utilities under the scenario where dispute does not occur under both centralized dispute systems to determine which centralized dispute system is better, when contracting can take place under both decentralized dispute systems. If dispute does not occur, the difference $\Pi^* - \Pi_d^* = \gamma\frac{4\sigma\theta(y+\sigma)}{\gamma+4\sigma\theta} - \gamma\frac{4\sigma\theta(y+\sigma-2(1-\gamma)\sigma)}{\gamma+4\sigma\theta} \geq 0$.

Hence, the comparison is summarized as follows: Define

$$\tilde{\sigma} = \max\left(\frac{y}{3}, \min\left(\bar{\sigma}, \frac{\sqrt{(1-2\gamma)^2\gamma^2 + 32(1-\gamma)\gamma\theta y} - (1-2\gamma)\gamma}{16(1-\gamma)\theta}\right)\right),$$

$$\tilde{\alpha}_{dd} = \begin{cases} \frac{1-\gamma}{y+\sigma} & \text{if } \sigma \leq \frac{y}{3}, \\ \max\left(\frac{1-\gamma}{y-\sigma+2\gamma\sigma}, \frac{(1-4\gamma-\gamma^2)}{2(7-3\gamma)(y-\sigma)}\right) & \text{if } \frac{y}{3} < \sigma \leq \tilde{\sigma}, \end{cases}$$

and rewrite $\bar{\alpha}_d$ as $\tilde{\alpha}_d$. If $\gamma \leq \frac{1}{3}$ and $\sigma \leq \tilde{\sigma}$, we have

(a) $\Pi^+ \geq \Pi_d^+ \geq \max(\Pi^*, \Pi_d^*)$ if $\alpha \leq \tilde{\alpha}_{dd}$,

(b) $\Pi_d^+ \geq \Pi^+ \geq \max(\Pi^*, \Pi_d^*)$ if $\tilde{\alpha}_{dd} < \alpha \leq \tilde{\alpha}_d$,

(c) $\Pi_d^+ \geq \max(\Pi^*, \Pi_d^*) \geq \Pi^+$if $\tilde{\alpha}_d < \alpha \leq \bar{\alpha}_{dd}$,

(d) $\Pi^*, \Pi_d^* > \max(\Pi^+, \Pi_d^+)$ if $\alpha > \bar{\alpha}_{dd}$.

Therefore, the results given in Theorem 1.7 follow. □

## A.9 Proofs of Section 1.9.4 (Task Failure)

*Proof of Proposition 1.9* Proposition 1.9 can be proven by backward induction based on the decision tree in Figure 1.1.

At Stage 6, the platform makes the decision on the dispute, which will only occur if the client has rejected the freelancer's work and the freelancer has initiated the dispute. Given the realized quality $\tilde{q}$, the freelancer wins with probability $h^*(\tilde{q})$ and loses with probability 1-$h^*(\tilde{q})$, where each $h^*(\tilde{q})$ follows from Lemma 1.1.

At Stage 5, the freelancer makes the decision on whether to initiate the dispute, which will only occur if the client has rejected the freelancer's work. We need to analyze the freelancer's dispute decision under the two different possible realized quality levels, $\tilde{q} = q$ or $\tilde{q} = 0$. For both quality levels, the analysis follows from the proof of Proposition 1.1. Therefore, for $\tilde{q} = q$, the freelancer initiates the dispute if $h^*(q)(1-\gamma)p - f \geq 0$, and does not initiate the dispute if $h^*(q)(1-\gamma)p - f < 0$. Likewise, for $\tilde{q} = 0$, the freelancer initiates the dispute if $h^*(0)(1-\gamma)p - f \geq 0$, and does not initiate the dispute if $h^*(0)(1-\gamma)p - f < 0$.

At Stage 4, the client decides whether to accept or reject the freelancer's work. For $\tilde{q} = q$, $U_c = q - p$ if the client accepts. If the client rejects, her utility is

$$U_c(p) = \begin{cases} q - h^*(q)p & \text{if } h^*(q)(1-\gamma)p - f \geq 0, \\ q & \text{otherwise.} \end{cases}$$

Therefore, the client accepts if $(1-\gamma)p - f \geq 0$ and $h^*(q) = 1$. She rejects otherwise.

For $\tilde{q} = 0$, $U_c = -p$ if the client accepts. If the client rejects, her utility is

$$U_c(p) = \begin{cases} -h^*(0)p & \text{if } h^*(0)(1-\gamma)p - f \geq 0, \\ 0 & \text{otherwise.} \end{cases}$$

Therefore, the client always rejects.

At Stage 3, the freelancer decides whether to participate or not and chooses his quality level if he participates. If freelancer chooses $q_f^*$, such that the client accepts (i.e., $h^*(q_f^*) = 1$), then $q_f^*$ is given by

$$q_f^* = y + \sigma - \frac{\gamma p}{4\theta\sigma}.$$

If $(1-\gamma)p - f \geq 0$ and $h^*(0)(1-\gamma)p - f \geq 0$, the freelancer's expected utility is

$$\begin{aligned} U_{f,1} &= -\alpha(q_f^*)^2 + \beta(1-\gamma)p + (1-\beta)[h^*(0)(1-\gamma)p - f] \\ &= -\alpha(q_f^*)^2 + (\beta + (1-\beta)h^*(0))(1-\gamma)p - (1-\beta)f. \end{aligned}$$

If $(1-\gamma)p - f \geq 0$ and $h^*(0)(1-\gamma)p - f < 0$, the freelancer's expected utility is

$$U_{f,1} = -\alpha(q_f^*)^2 + \beta(1-\gamma)p.$$

Therefore,

$$U_{f,1} = \begin{cases} -\alpha(q_f^*)^2 + (\beta + (1-\beta)h^*(0))(1-\gamma)p - (1-\beta)f & \text{if } h^*(0)(1-\gamma)p - f \geq 0, \\ -\alpha(q_f^*)^2 + \beta(1-\gamma)p & \text{if } h^*(0)(1-\gamma)p - f < 0. \end{cases}$$

If the freelancer chooses $q_f^*$ such that the client always rejects (i.e., $h^*(q_f^*) < 1$), the freelancer's expected utility is

$$U_{f,2} = \begin{cases} -\alpha q^2 + (\beta h^*(q) + (1-\beta)h^*(0))(1-\gamma)p - f & \text{if } h^*(0)(1-\gamma)p - f \geq 0, \\ -\alpha q^2 + \beta h^*(q)(1-\gamma)p - \beta f & \text{if } h^*(0)(1-\gamma)p - f < 0. \end{cases}$$

Based on the first order condition, the freelancer's optimal quality level is

$$q_f^* = \frac{\beta(1-\gamma)p}{4\sigma\alpha}. \tag{A.69}$$

Therefore, the freelancer's optimal quality level is

$$q_f^* = \begin{cases} y + \sigma - \frac{\gamma p}{4\theta\sigma} & \text{if } U_{f,1} - U_{f,2} \geq 0, \\ \frac{\beta(1-\gamma)p}{4\sigma\alpha} & \text{if } U_{f,1} - U_{f,2} < 0. \end{cases}$$

Following the proof of Proposition 1.1 ,$U_{f,1} - U_{f,2} \geq 0$ can be represented as $\alpha \leq \underline{\alpha}_{cf}$, where $\alpha_{cf}$ is the $\alpha$ threshold such that $U_{f,1} = U_{f,2}$ when the freelancer faces the risk of task failure. Therefore, the freelancer's optimal quality level is

$$q_f^* = \begin{cases} y + \sigma - \frac{\gamma p}{4\theta\sigma} & \text{if } \alpha \leq \underline{\alpha}_{cf}, \\ \frac{\beta(1-\gamma)p}{4\sigma\alpha} & \text{if } \alpha > \underline{\alpha}_{cf}. \end{cases}$$

After the freelancer has completed the work, the actual work quality $\tilde{q}$ is realized. Hence, $\tilde{q} = q$ with probability $\beta$, and $\tilde{q} = 0$ with probability $1 - \beta$.

At Stage 2, the client decides whether to participate or not and if she participates, she chooses the price to offer to the freelancer, subject to the freelancer's individual rationality constraint.

(a) If $\alpha \leq \underline{\alpha}_{cf}$, the client's expected utility is given by

$$U_c(p) = \begin{cases} \beta q_f^* - (\beta + (1-\beta)h^*(0))p & \text{if } h^*(0)(1-\gamma)p - f \geq 0, \\ \beta(q_f^* - p) & \text{if } h^*(0)(1-\gamma)p - f < 0. \end{cases}$$

Since the client's utility is decreasing in $p$ and $\beta(q_f^* - p) \geq \beta q_f^* - (\beta + (1-\beta)h^*(0))p$, she chooses $p$ such that $(1-\gamma)p - f \geq 0$, $h^*(0)(1-\gamma)p - f < 0$ and $-\alpha(q_f^*)^2 + \beta(1-\gamma)p \geq 0$ for the freelancer to participate. In this case, the client's utility is $\beta(q_f^* - p)$. Hence, her optimal price is $p_f^* = \max(\frac{\alpha(q_f^*)^2}{\beta(1-\gamma)}, \frac{f}{1-\gamma})$ and $p_f^* < \frac{f}{h^*(0)(1-\gamma)}$. If $q_f^* - p_f^* \geq 0$, the client participates. If $q_f^* - p_f^* < 0$, the client does not participate. Therefore, the client accepts with probability $\beta$.

(b) If $\alpha > \underline{\alpha}_{cf}$, then the client's utility is given by

$$U_c(p) = \begin{cases} \beta q_f^* - (\beta h^*(q_f^*) + (1-\beta)h^*(0))p & \text{if } h^*(0)(1-\gamma)p - f \geq 0, \\ \beta(q_f^* - h^*(q_f^*)p) & \text{if } h^*(0)(1-\gamma)p - f < 0. \end{cases}$$

Note that the client's optimal contract price depends on the dispute fee and the client can always perform better under $\beta(q_f^* - h^*(q_f^*)p)$. Under both cases of $h^*(0)(1-\gamma)p - f \geq 0$ and $h^*(0)(1-\gamma)p - f < 0$, the analysis for Stage 2 to obtain $p_f^*$ follows from the proof of Proposition 1.1.

At Stage 1, the platform chooses the dispute fee $f$ while satisfying the individual rationality constraints of the client and the freelancer.

(a) If $\alpha \leq \underline{\alpha}_{cf}$, recall from previous analyses that if both the client and the freelancer participate, the client offers price $p_f^* = \max(\frac{\alpha(q_f^*)^2}{\beta(1-\gamma)}, \frac{f}{1-\gamma})$ and $p_f^* < \frac{f}{h^*(0)(1-\gamma)}$, and the freelancer chooses quality $q_f^* = y + \sigma - \frac{\gamma p_f^*}{4\theta\sigma}$. Thus, the platform will achieve a utility of $\Pi(f) = \beta\gamma p_f^* = \beta\gamma \max(\frac{\alpha(q_f^*)^2}{\beta(1-\gamma)}, \frac{f}{1-\gamma})$. The platform's optimization problem is as follows:

$$\max_{f\geq 0} \quad \beta\gamma \max\left(\frac{\alpha(q_f^*)^2}{\beta(1-\gamma)}, \frac{f}{1-\gamma}\right),$$

$$\text{s.t.} \quad \beta\left(q_f^* - \max\left(\frac{\alpha(q_f^*)^2}{\beta(1-\gamma)}, \frac{f}{1-\gamma}\right)\right) \geq 0, \tag{A.70}$$

$$-\alpha(q_f^*)^2 + \beta(1-\gamma)\max\left(\frac{\alpha(q_f^*)^2}{\beta(1-\gamma)}, \frac{f}{1-\gamma}\right) \geq 0, \tag{A.71}$$

where Equation (A.70) is the individual rationality constraint of the client, and Equation (A.71) is the individual rationality constraint of the freelancer.

Notice from the above problem formulation that the case of $\frac{f}{1-\gamma} \leq \frac{\alpha(q_f^*)^2}{\beta(1-\gamma)}$ is equivalent to $\frac{f}{1-\gamma} = \frac{\alpha(q_f^*)^2}{\beta(1-\gamma)}$. We thus focus on $\frac{f}{1-\gamma} \geq \frac{\alpha(q_f^*)^2}{\beta(1-\gamma)}$, or equivalently, $f \geq \frac{\alpha(q_f^*)^2}{\beta}$. In this case, the platform's utility reduces to $\Pi = \beta\frac{\gamma f}{1-\gamma}$, Equation (A.70) reduces to $f \leq (1-\gamma)q_f^*$, and Equation (A.71) reduces to $f \geq \frac{\alpha(q_f^*)^2}{\beta}$. Thus, if $\frac{\alpha(q_f^*)^2}{\beta} > \frac{(1-\gamma)\beta q_f^*}{\beta}$, or equivalently, $\alpha q_f^* > (1-\gamma)\beta$, the problem is infeasible. If $\alpha q_f^* \leq (1-\gamma)\beta$, since $\Pi$ is increasing in $f$, $f_f^* = (1-\gamma)q_f^*$, which also satisfies $f_f^* \geq \frac{\alpha(q_f^*)^2}{\beta}$. Since $p_f^* = \frac{f_f^*}{1-\gamma}$, we have $q_f^* = p_f^*$ and $p_f^* < \frac{f_f^*}{h^*(0)(1-\gamma)}$ is also satisfied. Therefore, $q_f^* = \frac{4\sigma\theta(y+\sigma)}{\gamma+4\sigma\theta}$ and $p_f^* = \frac{4\sigma\theta(y+\sigma)}{\gamma+4\sigma\theta}$. Hence, we have $\Pi_f^* = \beta\gamma\frac{4\sigma\theta(y+\sigma)}{\gamma+4\sigma\theta}$ if $\alpha \leq \underline{\alpha}_{cf} = \frac{\beta(1-\gamma)(\gamma+4\sigma\theta)}{4\sigma\theta(y+\sigma)}$.

(b) If $\alpha > \underline{\alpha}_{cf}$, the client rejects the freelancer's work. In this case, the platform faces two sub-problems, which depends on whether $h^*(0)(1-\gamma)p_f^* \geq f$ or $h^*(0)(1-\gamma)p_f^* < f$. We define problem (i) as the scenario where $h^*(0)(1-\gamma)p_f^* \geq f$, and problem (ii) as the scenario where $h^*(0)(1-\gamma)p_f^* < f$. Thus, if $h^*(0)(1-\gamma)p_f^* \geq f$ (i.e., the freelancer initiates dispute when the realized quality level is 0), the platform's problem (i) is

$$\max_{f\geq 0} \quad (\beta h^*(q_f^*) + (1-\beta)h^*(0))\gamma p_f^* + f - \frac{\gamma^2(p_f^*)^2}{16\theta\sigma^2},$$

$$\text{s.t.} \quad \beta q_f^* - (\beta h^*(q_f^*) + (1-\beta)h^*(0))p_f^* \geq 0, \tag{A.72}$$

$$-\alpha(q_f^*)^2 + (\beta h^*(q_f^*) + (1-\beta)h^*(0))(1-\gamma)p_f^* - f \geq 0, \tag{A.73}$$

where Equation (A.72) is the individual rationality constraint of the client, and

Equation (A.73) is the individual rationality constraint of the freelancer. Second, if $h^*(0)(1-\gamma)p_f^* < f$ (i.e., the freelancer does not initiate dispute when the realized quality level is 0), the platform's problem (ii) is instead

$$\max_{f\geq 0} \quad \beta h^*(q_f^*)\gamma p_f^* + \beta f - \beta\frac{\gamma^2(p_f^*)^2}{16\theta\sigma^2},$$

$$\text{s.t.} \quad \beta q_f^* - \beta h^*(q_f^*)p_f^* \geq 0, \tag{A.74}$$

$$-\alpha(q_f^*)^2 + \beta h^*(q_f^*)(1-\gamma)p_f^* - \beta f \geq 0, \tag{A.75}$$

where Equation (A.74) is the individual rationality constraint of the client, and Equation (A.75) is the individual rationality constraint of the freelancer. Similar to the proof of Proposition 1.1, $\Pi$ is increasing in $f$ in both problems.

(i) In the first problem, $f_f^*$ is chosen such that constraints (A.72) and (A.73) are binding. Thus, from the binding Equation (A.72), we have

$$\begin{aligned}
&\beta q_f^* - \left(\frac{\beta q_f^* - y + \sigma}{2\sigma} + \frac{\gamma p_f^*}{8\theta\sigma^2}\right)p_f^* = 0 \\
\Leftrightarrow\ &\frac{\beta^2(1-\gamma)}{4\alpha\sigma} - \left(\frac{\frac{\beta^2(1-\gamma)p_f^*}{4\alpha\sigma} - y + \sigma}{2\sigma} + \frac{\gamma p_f^*}{8\theta\sigma^2}\right) = 0 \\
\Leftrightarrow\ &p_f^* = \frac{2\sigma\theta(2\alpha(y-\sigma) + \beta^2(1-\gamma))}{\gamma\alpha + \beta^2(1-\gamma)\theta},
\end{aligned}$$

where the first step follows from $h^*(q_f^*) = \frac{q_f^* - y + \sigma}{2\sigma} + \frac{\gamma p_f^*}{8\theta\sigma^2}$ and the second step follows from Equation (A.69). Consequently, from Equation (A.69), we have

$$q_f^* = \frac{\beta(1-\gamma)\theta(2\alpha(y-\sigma) + \beta^2(1-\gamma))}{2\alpha(\gamma\alpha + \beta^2(1-\gamma)\theta)}.$$

Substituting $p_f^*$ and $q_f^*$ into the binding Equation (A.73), we obtain

$$f_f^* = \frac{\beta^2(1-\gamma)^2\theta\left(2\alpha(y-\sigma) + \beta^2(1-\gamma)\right)\left(2\alpha(\gamma - \theta(y-\sigma)) + \beta^2(1-\gamma)\theta\right)}{4\alpha\left(\gamma\alpha + \beta^2(1-\gamma)\theta\right)^2}.$$

Finally, we check that $h^*(0)(1-\gamma)p_f^* \geq f_f^*$ is always true in this case. We have $h^*(0)(1-\gamma)p_f^* - f_f^* = -\frac{\beta^2(1-\gamma)^2\theta^2\left(2\alpha(y-\sigma)+\beta^2(1-\gamma)\right)^2}{4\alpha\left(\gamma\alpha+\beta^2(1-\gamma)\theta\right)^2} < 0$ for $\beta > 0$. Therefore, the condition is violated and the platform chooses $f_f^* = h^*(0)(1-\gamma)p_f^*$ instead, such that the freelancer is indifferent between initiating the dispute and not initiating the dispute if the client rejects his work when the realized quality level is 0. In this case, the freelancer's utility from Equation (A.73) is $U_f = -\alpha(q_f^*)^2 - \beta h^*(q_f^*)(1-\gamma)p_f^* - \beta f_f^*$. Recall that client's utility from Stage 2 is always higher if she optimizes under the utility $U_c = \beta q_f^* - \beta h^*(q_f^*)p$ than the utility $U_c = \beta q_f^* - (\beta h^*(q_f^*) + (1-\beta)h^*(0))p$. Thus, since her optimization problem is subject to $U_f = -\alpha(q_f^*)^2 - \beta h^*(q_f^*)(1-\gamma)p_f^* - \beta f_f^* \geq 0$, which is the same as the second problem (ii), the platform is better off maximizing the second problem where it is able to extract more surplus.

(ii) As the platform is better off maximizing the second problem, where the freelancer does not initiate the dispute when the realized quality level is 0, we proceed to analyze problem (ii). $f_f^*$ is chosen such that Equations (A.74) and (A.75) are binding. From the binding Equation (A.74), we have

$$\beta q_f^* - \beta\left(\frac{q_f^* - y + \sigma}{2\sigma} + \frac{\gamma p_f^*}{8\theta\sigma^2}\right)p_f^* = 0$$
$$\Leftrightarrow \frac{\beta(1-\gamma)}{4\alpha\sigma} - \left(\frac{\frac{\beta(1-\gamma)p_f^*}{4\alpha\sigma} - y + \sigma}{2\sigma} + \frac{\gamma p_f^*}{8\theta\sigma^2}\right) = 0$$
$$\Leftrightarrow p_f^* = \frac{2\sigma\theta(2\alpha(y-\sigma) + \beta(1-\gamma))}{\gamma\alpha + \beta(1-\gamma)\theta},$$

where the first step follows from $h^*(q_f^*) = \frac{q_f^* - y + \sigma}{2\sigma} + \frac{\gamma p_f^*}{8\theta\sigma^2}$ and the second step follows from Equation (A.69). Consequently, from Equation (A.69), we have

$$q_f^* = \frac{\beta(1-\gamma)\theta(2\alpha(y-\sigma) + \beta(1-\gamma))}{2\alpha(\gamma\alpha + \beta(1-\gamma)\theta)}.$$

Substituting $p_f^*$ and $q_f^*$ into the binding Equation (A.75), we obtain

$$f_f^* = \frac{\beta(1-\gamma)^2\theta(2\alpha(y-\sigma) + \beta(1-\gamma))(2\alpha(\gamma - \theta(y-\sigma)) + \beta(1-\gamma)\theta)}{4\alpha(\gamma\alpha + \beta(1-\gamma)\theta)^2}.$$

Therefore, we have

$$\Pi_f^* = \frac{1}{4\alpha(\gamma\alpha - \beta(1-\gamma)\theta)^2}\Big[\beta\theta(2\alpha(y-\sigma) + \beta(1-\gamma))(-2\gamma^2\alpha^2(y-\sigma) + \alpha\beta(1-\gamma)((2-\gamma)\gamma - 2\gamma\sigma\theta - 2(1-\gamma)\theta y + 2\sigma\theta) + \beta^2(1+\gamma)(1-\gamma)^2\theta)\Big].$$

Moreover, since dispute fee has to be non-negative for contracting to occur, if $\sigma > y$, $f_f^* = 0$ at $\alpha = \frac{\beta(1-\gamma)}{2(\sigma-y)}$. If $\sigma \le y - \frac{\gamma}{\theta}$, $f_f^* = 0$ at $\alpha = \frac{\beta(1-\gamma)\theta}{2(\theta(y-\sigma)-\gamma)}$. If $y - \frac{\gamma}{\theta} < \sigma \le y$, $f_f^* \ge 0$ for all $\alpha$. Therefore, if dispute occurs, there exists a threshold, $\hat{\alpha}_{cf}$, such that $f_f^* \ge 0$ if and only if $\alpha \le \hat{\alpha}_{cf}$, where $\hat{\alpha}_{cf}$ is given by

$$\hat{\alpha}_{cf} = \begin{cases} \frac{\beta(1-\gamma)\theta}{2(\theta(y-\sigma)-\gamma)} & \text{if } \sigma \le y - \frac{\gamma}{\theta}, \\ \infty & \text{if } y - \frac{\gamma}{\theta} < \sigma \le y, \\ \frac{\beta(1-\gamma)}{2(\sigma-y)} & \text{if } \sigma > y. \end{cases}$$

If $\alpha > \hat{\alpha}_{cf}$, since the dispute fee has to be non-negative, setting $f_f^* = 0$ would cause the individual rationality constraint of the freelancer to be violated. We define $\bar{\alpha}_{cf} = \max(\underline{\alpha}_{cf}, \hat{\alpha}_{cf})$. Contracting occurs if and only if $\alpha \le \bar{\alpha}_{cf}$. Thus, given that contracting occurs, dispute occurs in equilibrium if and only if $\underline{\alpha}_{cf} < \alpha \le \bar{\alpha}_{cf}$.

Finally, we compare the thresholds to the main model. Comparing $\underline{\alpha}_{cf}$ with $\underline{\alpha}_c$, we have $\underline{\alpha}_{cf} - \underline{\alpha}_c = \frac{\beta(1-\gamma)(\gamma+4\sigma\theta)}{4\sigma\theta(y+\sigma)}(\beta - 1) < 0$ and thus, $\underline{\alpha}_{cf} \le \underline{\alpha}_c$. Comparing $\bar{\alpha}_{cf}$ with $\bar{\alpha}_c$, since $\hat{\alpha}_{cf} = \beta\hat{\alpha}_c$ and $\bar{\alpha}_{cf} = \max(\underline{\alpha}_{cf}, \hat{\alpha}_{cf})$ and $\bar{\alpha}_c = \max(\underline{\alpha}_d, \hat{\alpha}_c)$, we have $\bar{\alpha}_{cf} \le \bar{\alpha}_c$. □

*Proof of Proposition 1.10* Proposition 1.10 can be proven by backward induction based on the decision tree in Figure 1.1.

At Stage 6, the tribunal makes the decision on the dispute, which only occurs if the client has rejected the freelancer's work and the freelancer has initiated the dispute. Given the realized quality $\tilde{q}$, the freelancer wins with probability $h^+(\tilde{q})$ and loses with probability 1-$h^+(\tilde{q})$, where each $h^+(\tilde{q})$ follows from Lemma 1.2.

Similar to the proof of Proposition 1.9, the analysis for Stages 2 to 5 to obtain $q_f^+$ and $p_f^+$ follows from the proof of Proposition 1.3, where if $\alpha \le \underline{\alpha}_{df}$, $q_f^+ = y + \sigma$. If $\alpha > \underline{\alpha}_{df}$, $q_f^+$ is given by the solution of

$$q_f^+ = \frac{\beta(1-\gamma)p_f^+}{4\sigma\alpha}. \tag{A.76}$$

At Stage 1, the platform chooses the dispute fee $f$ while satisfying the individual rationality constraints of the client and the freelancer.

(a) If $\alpha \le \underline{\alpha}_{df}$, following the proof of Proposition 1.3, $\Pi_f^+ = \beta\gamma p_f^+ = \beta\gamma(y+\sigma)$ and $\underline{\alpha}_{df} = \frac{\beta(1-\gamma)}{y+\sigma}$.

(b) If $\alpha > \underline{\alpha}_{df}$, dispute occurs and the platform's problem, following the similar steps as the proof of Proposition 1.9 with $h^*(q)$ being replaced by $h^+(q)$, is

$$\max_{f\ge 0} \quad \beta h^+(q_f^+)\gamma p_f^+ + f$$

$$\text{s.t.} \quad \beta q_f^+ - \beta h^+(q_f^+)p_f^+ \ge 0, \tag{A.77}$$

$$-\alpha(q_f^+)^2 + \beta h^+(q_f^+)(1-\gamma)p_f^+ - \beta f \ge 0, \tag{A.78}$$

where Equation (A.77) is the individual rationality constraint of the client, and Equation (A.78) is the individual rationality constraint of the freelancer. Similar to the proof of Proposition 1.3, $\Pi$ is increasing in $f$. Therefore, $f_f^+$ is chosen such that $U_c^+ = U_f^+ = 0$. Thus, from the binding Equation (A.77), we have

$$p_f^+ = \frac{q_f^+}{h^+(q_f^+)}. \tag{A.79}$$

Substituting Equation (A.79) into Equation (A.76), we have

$$q_f^+ = \frac{\beta(1-\gamma)}{2\alpha} + y - \sigma.$$

Consequently, from Equation (A.76), we have

$$p_f^+ = \frac{4\alpha\sigma(y-\sigma)}{\beta(1-\gamma)} + 2\sigma.$$

Substituting $p_f^+$ and $q_f^+$ into the binding Equation (A.78), we obtain

$$f_f^+ = \frac{(2\alpha(y-\sigma)+\beta(1-\gamma))(-2\alpha(y-\sigma)+\beta(1-\gamma-1))}{4\alpha\beta}.$$

Therefore, we have

$$\Pi_f^+ = \frac{(2\alpha(y-\sigma)+\beta(1-\gamma))(-2\alpha(y-\sigma)+\beta(1+(2\beta-1)\gamma))}{4\alpha\beta}.$$

Moreover, since dispute fee has to be non-negative for contracting to occur, if $\sigma > y$, $f_f^+ = 0$ at $\alpha = \frac{\beta(1-\gamma)}{2(\sigma-y)}$. If $\sigma \leq y$, $f_f^+ = 0$ at $\alpha = \frac{\beta(1-\gamma)}{2(y-\sigma)}$. Therefore, if dispute occurs, there exists a threshold $\hat{\alpha}_{df}$, which is the solution of $f_f^+ = 0$, such that $f_f^+ \geq 0$ if and only if $\alpha \leq \hat{\alpha}_{df}$, where $\hat{\alpha}_{df}$ is given by

$$\hat{\alpha}_{df} = \begin{cases} \frac{\beta(1-\gamma)}{2(y-\sigma)} & \text{if } \sigma \leq y, \\ \frac{\beta(1-\gamma)}{2(\sigma-y)} & \text{if } \sigma > y. \end{cases}$$

If $\alpha > \hat{\alpha}_{df}$, since the dispute fee has to be non-negative, setting $f_f^+ = 0$ would cause the individual rationality constraint of the freelancer to be violated. We define $\bar{\alpha}_{df} = \max(\underline{\alpha}_{df}, \hat{\alpha}_{df})$. Contracting occurs if and only if $\alpha \leq \bar{\alpha}_{df}$. Thus, given that contracting occurs, dispute occurs in equilibrium if and only if $\underline{\alpha}_{df} < \alpha \leq \bar{\alpha}_{df}$.

Finally, we compare the thresholds to the main model under $\sigma \leq y$. Comparing $\underline{\alpha}_{df}$ with $\underline{\alpha}_d$, we have $\underline{\alpha}_{df} - \underline{\alpha}_d = \frac{1-\gamma}{y+\sigma}(\beta-1) \leq 0$ and thus, $\underline{\alpha}_{df} \leq \underline{\alpha}_d$. Comparing $\bar{\alpha}_{df}$ with $\bar{\alpha}_d$, since $\hat{\alpha}_{df} = \beta\hat{\alpha}_d$ and $\bar{\alpha}_{df} = \max(\underline{\alpha}_{df}, \frac{\beta(1-\gamma)}{2(y-\sigma)})$ and $\bar{\alpha}_d = \max(\underline{\alpha}_d, \frac{1-\gamma}{2(y-\sigma)})$, we have $\bar{\alpha}_{df} \leq \bar{\alpha}_d$. □

*Proof of Theorem 1.8* Following Propositions 1.9 and 1.10 , we compare the platform's equilibrium utilities under the centralized and decentralized dispute systems. Following Propositions 1.9 and 1.10, we know that $\underline{\alpha}_{cf} = \beta\underline{\alpha}_c$ and $\underline{\alpha}_{df} = \beta\underline{\alpha}_d$ and thus, $\underline{\alpha}_{df} \leq \underline{\alpha}_{cf}$. Similarly, $\bar{\alpha}_{cf} = \beta\bar{\alpha}_c$ and $\bar{\alpha}_{df} = \beta\bar{\alpha}_d$ and thus, $\bar{\alpha}_{df} \leq \bar{\alpha}_{cf}$. Therefore, if $\sigma \leq \bar{\sigma}$, from the proof of Theorem 1.3, $\bar{\alpha}_{df} \leq \bar{\alpha}_{cf}$ as $\bar{\alpha}_d \leq \bar{\alpha}_c$. Thus, there are two cases for comparisons (i.e., $\alpha \le \underline{\alpha}_{df}$ or $\underline{\alpha}_{df} < \alpha \le \underline{\alpha}_{cf}$). If dispute does not occur under either system (i.e., $\alpha \le \underline{\alpha}_{df}$), $p_f^+ = \beta(y+\gamma) \ge \frac{4\sigma\theta(y+\sigma)}{\gamma+4\sigma\theta} = p_f^*$. Therefore, $\Pi_f^+ = \beta\gamma p^+ \ge \beta\gamma p^* = \Pi_f^*$.

If dispute occurs under the decentralized dispute system and does not occur under the centralized dispute system (i.e., $\underline{\alpha}_{df} < \alpha \le \underline{\alpha}_{cf}$), recall from Proposition 1.9 that $q_f^* = \frac{4\sigma\theta(y+\sigma)}{\gamma+4\sigma\theta}$ and from Proposition 1.10 that $q_f^+ = \frac{\beta(1-\gamma)}{2\alpha} + y - \sigma$. It is easy to see that the difference $q_f^+ - q_f^*$ is decreasing in $\alpha$. Taking the difference between the two quality levels at $\underline{\alpha}_{cf}$, we have $q_f^+ - q_f^* = \frac{\beta(1-\gamma)}{2\underline{\alpha}_{cf}} + y - \sigma - \frac{4\sigma\theta(y+\sigma)}{\gamma+4\sigma\theta} = -\frac{2\sigma\theta(\sigma+y)}{\gamma+4\sigma\theta} - \sigma + y \ge 0$ if $\sigma \le \bar{\sigma}$, following the proof in Theorem 1.2. Therefore, $q_f^+ \ge q_f^*$. Consequently, $\Pi_f^+ = \beta h(q_f^+)\gamma p_f^+ + f_f^+ = \beta\gamma q_f^+ + f_f^+ \ge \beta\gamma q_f^* = \Pi_f^*$ as $q_f^+ - q_f^* \ge 0$. Thus, the decentralized dispute system is only better than the centralized dispute system as long as contracting occurs for the decentralized dispute system (i.e., $\Pi_f^+ \ge \Pi_f^*$ if and only if $\alpha \le \max(\underline{\alpha}_{df}, \frac{\beta(1-\gamma)}{2(y-\sigma)}) = \bar{\alpha}_{df}$). We can alternatively express the condition $\alpha \le \bar{\alpha}_{df}$ as $\beta \ge \frac{\alpha}{\bar{\alpha}_d}$ since $\bar{\alpha}_{df} = \beta\bar{\alpha}_d$. Therefore, there exists a threshold $\bar{\beta}$, where $\bar{\beta} = \frac{\alpha}{\bar{\alpha}_d}$, such that $\Pi_f^+ \ge \Pi_f^*$ if and only if $\beta \ge \bar{\beta}$. □

## A.10 Proofs of Section 1.9.5 (Differential Subjectivity between Platform and Voters)

*Proof of Theorem 1.9* Let $\sigma_c$ denote the degree of subjectivity under the centralized dispute system and $\sigma_d$ denote the degree of subjectivity under the decentralized dispute system, where $\sigma_c \le \sigma_d$. Thus, the respective equilibrium outcomes follow directly from Proposition 1.1 and 1.3 with $\sigma$ being replaced by $\sigma_c$ under the centralized dispute system and $\sigma$ being replaced by $\sigma_d$ under the decentralized dispute system.

We first prove there exists a threshold $\bar{\alpha}_s$ such that $\Pi_s^+ \ge \Pi_s^*$ if $\alpha \le \bar{\alpha}_s$. To prove this, we first compare the platform's equilibrium utilities between the centralized and decentralized dispute systems if dispute does not occur under either system (i.e., $\alpha \leq \min(\underline{\alpha}_{cs}, \underline{\alpha}_{ds})$). In this case, under the centralized dispute system, $\Pi_s^* = \frac{4\gamma\sigma_c\theta(y+\sigma_c)}{\gamma+4\sigma_c\theta}$; under the decentralized dispute system, $\Pi_s^+ = \gamma(y + \sigma_d)$. Therefore, it is easy to see that $\Pi_s^+ \geq \Pi_s^*$ if $\alpha \leq \min(\underline{\alpha}_{cs}, \underline{\alpha}_{ds})$. Hence, there exists a threshold $\bar{\alpha}_s$, where $\bar{\alpha}_s \geq \min(\underline{\alpha}_{cs}, \underline{\alpha}_{ds})$, such that $\Pi_s^+ \geq \Pi_s^*$ if $\alpha \leq \underline{\alpha}_s$.

We now prove that if $\gamma \leq \frac{1}{3}$, $\sigma_c \leq y$, $\sigma_d \leq y$ and $\sigma_c \geq Z\sigma_d$, where $Z = \max(\frac{1}{1+\frac{\gamma}{\sigma_c\theta}}, \frac{2(1-2\gamma)\theta y+\gamma(\gamma-1)}{2\sigma_d(1-\gamma)\theta} + \frac{\gamma}{1-\gamma})$, the platform's equilibrium utility is higher under the decentralized dispute system (i.e., $\Pi_s^+ \geq \Pi_s^*$) if and only if $\alpha \leq \bar{\alpha}_s$. To prove this, we first compare the $\alpha$ thresholds under the different dispute systems. Under the centralized dispute system, $\underline{\alpha}_{cs} = \frac{(1-\gamma)(\gamma+4\sigma_c\theta)}{4\sigma_c\theta(y+\sigma_c)}$; under the decentralized dispute system, $\underline{\alpha}_{ds} = \frac{1-\gamma}{y+\sigma_d}$. Thus, the difference between $\underline{\alpha}_{ds}$ and $\underline{\alpha}_{cs}$ is $\underline{\alpha}_{ds} - \underline{\alpha}_{cs} = \frac{1-\gamma}{y+\sigma_d} - \frac{(1-\gamma)(\gamma+4\sigma_c\theta)}{4\sigma_c\theta(y+\sigma_c)} \leq \frac{1-\gamma}{y+\sigma_c} - \frac{(1-\gamma)(\gamma+4\sigma_c\theta)}{4\sigma_c\theta(y+\sigma_c)} = -\frac{\gamma(1-\gamma)^2}{4\sigma_c\theta(y+\sigma_c)} \leq 0$, where the second step follows from $\sigma_c \leq \sigma_d$. Hence, $\underline{\alpha}_{ds} \leq \underline{\alpha}_{cs}$. We next compare the $\alpha$ thresholds beyond which contracting does not occur between the centralized and decentralized dispute systems. Under the centralized dispute system, $\bar{\alpha}_{cs} = \max(\underline{\alpha}_c, \frac{(1-\gamma)\theta}{2(\theta(y-\sigma_c)-\gamma)})$ if $\sigma_c \leq y - \frac{\gamma}{\theta}$ and $\bar{\alpha}_{cs} \to \infty$ if $y - \frac{\gamma}{\theta} < \sigma_c \leq y$; under the decentralized dispute system, $\bar{\alpha}_{ds} = \max(\underline{\alpha}_{ds}, \frac{1-\gamma}{2(y-\sigma_d)})$. If $y - \frac{\gamma}{\theta} < \sigma_c \leq y$, we can obtain $f^* \geq 0$ for all $\alpha$ under the centralized dispute system from Equation (A.12), and thus, $\bar{\alpha}_{cs} \geq \bar{\alpha}_{ds}$. If $\sigma_c \leq y - \frac{\gamma}{\theta}$, as we know from the above that $\underline{\alpha}_{ds} \leq \underline{\alpha}_{cs}$, we now compare the case where $\bar{\alpha}_{ds} = \frac{1-\gamma}{2(y-\sigma_d)}$ with $\bar{\alpha}_{cs} = \frac{(1-\gamma)\theta}{2(\theta(y-\sigma_c)-\gamma)}$. We obtain $\bar{\alpha}_{ds} - \bar{\alpha}_{cs} = \frac{(1-\gamma)(\theta(\sigma_d-\sigma_c)-\gamma)}{2(\theta(y-\sigma_c)-\gamma)(y-\sigma_d)}$, which is negative if $\sigma_c \geq \frac{1}{1+\frac{\gamma}{\sigma_c\theta}}\sigma_d$. Therefore, if $\sigma_c \geq \frac{1}{1+\frac{\gamma}{\sigma_c\theta}}\sigma_d$, we have $\bar{\alpha}_{ds} \leq \bar{\alpha}_{cs}$.

After comparing the thresholds, we now compare the platform's equilibrium utilities between the centralized and decentralized dispute systems under the different regions of $\alpha$.

(a) If $\alpha \leq \underline{\alpha}_{ds}$, dispute does not occur under either system. In this case, as proven earlier, $\Pi_s^+ \geq \Pi_s^*$.

(b) If $\underline{\alpha}_{ds} < \alpha \leq \underline{\alpha}_{cs}$, taking the derivative of $\Pi_s^*$ with respect to $\sigma_c$, we have $\frac{\partial \Pi_s^*}{\partial \sigma_c} = \frac{4\gamma\theta(4\sigma_c^2\theta+\gamma(y+2\sigma_c))}{(\gamma+4\sigma_c\theta)^2} > 0$. Thus, since we know from Theorem 1.2 that when $\sigma_c = \sigma_d = \sigma$, $\Pi_s^+ \geq \Pi_s^*$ as long as contracting can occur within $\underline{\alpha}_d < \alpha \leq \underline{\alpha}_c$, if $\sigma_c$ decreases such that $\sigma_c \leq \sigma_d$, $\Pi_s^*$ remains smaller than $\Pi_s^+$ since $\Pi_s^+$ is constant in $\sigma_c$ and $\Pi_s^*$ is increasing in $\sigma_c$. Hence, $\Pi_s^+ \geq \Pi_s^*$ as long as contracting can occur within $\underline{\alpha}_{ds} < \alpha \leq \underline{\alpha}_{cs}$. Moreover, $\frac{\partial}{\partial \sigma_d}(\Pi_s^+ - \Pi_s^*) \leq 0$ for $\alpha \leq \underline{\alpha}_{cs}$.

(c) If $\alpha > \underline{\alpha}_{cs}$, dispute occurs under both systems. In this case, under the centralized dispute system,

$\Pi_s^* = \frac{\theta(2\alpha(y-\sigma_c)+(1-\gamma))\left(-2\gamma^2\alpha^2(y-\sigma_c)+(1-\gamma)\alpha((2-\gamma)\gamma-2\gamma\sigma_c\theta-2(1-\gamma)\theta y+2\sigma_c\theta)+(1+\gamma)(1-\gamma)^2\theta\right)}{4\alpha(\gamma\alpha+(1-\gamma)\theta)^2}$; under the decentralized dispute system, $\Pi_s^+ = \frac{(2\alpha(y-\sigma_d)+(1-\gamma))(-2\alpha(y-\sigma_d)+(1+\gamma))}{4\alpha}$. Thus, taking the derivative of $\Pi_s^+ - \Pi_s^*$ with respect to $\sigma_d$, we have

$$\begin{aligned}\frac{\partial \Pi_c^*}{\partial \sigma_c} &= \frac{\theta\left(2\alpha^2\gamma^2(y-\sigma_c)+\alpha(1-\gamma)^2(-\gamma+2\theta(y-\sigma_c))-\gamma(1-\gamma)^2\phi\theta\right)}{(\alpha\gamma-\gamma\theta+\theta)^2} \\ &\geq 0,\end{aligned}$$

if $\alpha \geq \frac{\gamma\theta}{2\theta(y-\sigma_c)-\gamma}$. Comparing $\frac{\gamma\theta}{2\theta(y-\sigma_c)-\gamma}$ with $\bar{\alpha}_d$, we have $\frac{\gamma\theta}{2\theta(y-\sigma_c)-\gamma} - \bar{\alpha}_d = \frac{\gamma\theta}{2\theta(y-\sigma_c)-\gamma} - \frac{1-\gamma}{2(y-\sigma_d)} \geq 0$ if $\sigma_c \geq \frac{2(1-2\gamma)\theta y+\gamma(\gamma+2\sigma_d\theta-1)}{2(1-\gamma)\theta} = \frac{2(1-2\gamma)\theta y+\gamma(\gamma-1)}{2(1-\gamma)\theta} + \frac{\gamma}{1-\gamma}\sigma_d$. Thus, if $\sigma_c \geq (\frac{2(1-2\gamma)\theta y+\gamma(\gamma-1)}{2\sigma_d(1-\gamma)\theta} + \frac{\gamma}{1-\gamma})\sigma_d$, $\frac{\partial \Pi_s^*}{\partial \sigma_c} > 0$. Since $\frac{\partial}{\partial \sigma_d}(\Pi_s^+ - \Pi_s^*) \leq 0$ if $\sigma_c \geq (\frac{2(1-2\gamma)\theta y+\gamma(\gamma-1)}{2\sigma_d(1-\gamma)\theta} + \frac{\gamma}{1-\gamma})\sigma_d$, and we know from Theorem 1.2 that when $\sigma_c = \sigma_d = \sigma$, $\Pi_s^+ \geq \Pi_s^*$ if and only if $\alpha \leq \bar{\alpha}$, $\Pi_s^+ - \Pi_s^*$ still crosses zero once as $\sigma_c$ increases. Thus, the above relationship is preserved if $\sigma_c \geq \max(\frac{1}{1+\frac{\gamma}{\sigma_c\theta}}, \frac{2(1-2\gamma)\theta y+\gamma(\gamma-1)}{2\sigma_d(1-\gamma)\theta} + \frac{\gamma}{1-\gamma})\sigma_d = Z$. Hence, combining all cases, if $\sigma_c \geq Z\sigma_d$, there exists a threshold $\bar{\alpha}_s$ such that $\Pi_s^+ \geq \Pi_s^*$ if and only if $\alpha \leq \bar{\alpha}_s$. □

## A.11 Proofs of Section 1.9.6 (Client's Reputation Loss)

*Proof of Proposition 1.11* Proposition 1.11 can be proven by backward induction based on the decision tree in Figure 1.1. The analysis for Stages 5 and 6 follows from the proof of Proposition 1.1 since the freelancer's utility remains unchanged. Therefore, the freelancer initiates the dispute if $h^*(q)(1-\gamma)p - f \geq 0$, and does not initiate the dispute otherwise.

At Stage 4, the client decides whether to accept or reject the freelancer's work. If the client accepts the freelancer's work, her utility is

$$U_c(p) = q - p.$$

If the client rejects the freelancer's work, she incurs a cost of $\phi q$ if dispute is initiated. Thus, her utility is

$$U_c(p) = \begin{cases} (1-\phi)q - h^*(q)p & \text{if } h^*(q)(1-\gamma)p - f \geq 0, \\ q & \text{if } h^*(q)(1-\gamma)p - f < 0. \end{cases}$$

Therefore, if $h^*(q)(1-\gamma)p - f \geq 0$, the client accepts if

$$\begin{aligned} q - p &\geq q - h^*(q)p - \phi q \\ \Leftrightarrow h^*(q) &\geq 1 - \frac{\phi q}{p}. \end{aligned}$$

If $h^*(q)(1-\gamma)p - f < 0$, since dispute is not initiated, the client always reject. Thus, the client's utility is then given by

$$U_c(p) = \begin{cases} q - p & \text{if } h^*(q) \geq 1 - \frac{\phi q}{p} \text{ and } h^*(q)(1-\gamma)p - f \geq 0, \\ q - h^*(q)p - \phi q & \text{if } h^*(q) < 1 - \frac{\phi q}{p} \text{ and } h^*(q)(1-\gamma)p - f \geq 0, \\ q & \text{if } h^*(q)(1-\gamma)p - f < 0. \end{cases}$$

At Stage 3, the freelancer decides whether to participate or not and chooses his quality level if he participates. Given that the freelancer participates, his utility is given by

$$U_f(q) = \begin{cases} -\alpha q^2 + (1-\gamma)p & \text{if } h^*(q) \geq 1 - \frac{\phi q}{p} \text{ and } h^*(q)(1-\gamma)p - f \geq 0, \\ -\alpha q^2 + h^*(q)(1-\gamma)p - f & \text{if } h^*(q) < 1 - \frac{\phi q}{p} \text{ and } h^*(q)(1-\gamma)p - f \geq 0, \\ -\alpha q^2 & \text{otherwise.} \end{cases}$$

If $h^*(q) \geq 1 - \frac{\phi q}{p}$ and $h^*(q)(1-\gamma)p - f \geq 0$, the freelancer's utility is decreasing in $q$, and hence his optimal quality level is

$$\begin{aligned} h^*(q) &= 1 - \frac{\phi q}{p} \\ \Leftrightarrow q - y + \frac{\gamma p}{4\theta\sigma} + \sigma &= 2\sigma - \frac{2\sigma\phi q}{p} \\ \Leftrightarrow q_l^* &= \frac{p(4\sigma\theta(y+\sigma) + \gamma p)}{4\sigma\theta(p + 2\phi\sigma)}. \end{aligned}$$

If $h^*(q) < 1 - \frac{\phi q}{p}$ and $h^*(q)(1-\gamma)p - f \geq 0$, the freelancer's optimal quality is $q_l^* = \frac{(1-\gamma)p}{4\sigma\alpha}$. Hence, following the proof of Proposition 1.1, if $h^*(q)(1-\gamma)p - f \geq 0$, the freelancer's optimal quality level is

$$q_l^* = \begin{cases} \frac{p(4\sigma\theta(y+\sigma)+\gamma p)}{4\sigma\theta(p+2\phi\sigma)} & \text{if } \alpha \leq \underline{\alpha}_{cl}, \\ \frac{(1-\gamma)p}{4\sigma\alpha} & \text{if } \alpha > \underline{\alpha}_{cl}, \end{cases}$$

where $\underline{\alpha}_{cl}$ is the $\alpha$ threshold to determine when dispute occurs.

At Stage 2, the client decides whether to participate or not and if she participates, she chooses the price to offer to the freelancer, subject to the freelancer's individual rationality constraint.

(a) If $\alpha \leq \underline{\alpha}_{cl}$ and $(1-\gamma)p - f \geq 0$, dispute does not occur and $q_l^* = \frac{p(4\sigma\theta(y+\sigma)+\gamma p)}{4\sigma\theta(p+2\phi\sigma)}$. Thus, the client's problem is

$$\begin{aligned} \max_{p \geq 0} \quad & q_l^* - p, \\ \text{s.t.} \quad & -\alpha(q_l^*)^2 + (1-\gamma)p \geq 0. \end{aligned}$$

Since the client's utility is decreasing in $p$, $p$ is chosen such that $(1-\gamma)p - f \geq 0$ and $-\alpha(q_l^*)^2 + (1-\gamma)p \geq 0$ for the freelancer to participate. Therefore, $p_l^* = \max(\frac{\alpha(q_l^*)^2}{1-\gamma}, \frac{f}{1-\gamma})$.

(b) If $\alpha > \underline{\alpha}_{cl}$ and $h^*(q_l^*)(1-\gamma)p - f \geq 0$, dispute occurs and $q_l^* = \frac{(1-\gamma)p}{4\sigma\alpha}$. The client's problem is

$$\begin{aligned} \max_{p\geq 0} \quad & q_l^* - h^*(q_l^*)p - \phi q_l^*, \\ \text{s.t.} \quad & -\alpha(q_l^*)^2 + h^*(q_l^*)(1-\gamma)p - f \geq 0. \end{aligned}$$

Notice that under this scenario, since the client's expected utility is of a similar form as our main model, the analysis for the client's optimal $p_l^*$ follows from the proof of Proposition 1.1.

At Stage 1, the platform chooses the dispute fee $f$ while satisfying the individual rationality constraints of the client and the freelancer.

(a) Recall from previous analyses that if $\alpha \leq \underline{\alpha}_{cl}$, dispute does not occur. The freelancer chooses quality $q_l^* = \frac{p_l^*(4\sigma\theta(y+\sigma)+\gamma p_l^*)}{4\sigma\theta(p_l^*+2\phi\sigma)}$ and the client offers price $p_l^* = \max(\frac{\alpha(q_l^*)^2}{1-\gamma}, \frac{f}{1-\gamma})$. Thus, the platform will achieve a utility of $\Pi(f) = \gamma p_l^* = \gamma \max(\frac{\alpha(q_l^*)^2}{1-\gamma}, \frac{f}{1-\gamma})$. Based on Equation (1.4), since $\Pi$ is increasing in $f$, we have

$$f_l^* = (1-\gamma)\frac{p_l^*(4\sigma\theta(y+\sigma)+\gamma p_l^*)}{4\sigma\theta(p_l^*+2\phi\sigma)},$$

and

$$p_l^* = q_l^* = \frac{4\sigma\theta(y+\sigma-2\phi\sigma)}{\gamma+4\sigma\theta}.$$

Hence, the platform's equilibrium utility is $\Pi_l^* = \gamma p_l^* = \frac{4\gamma\sigma\theta(y+\sigma-2\phi\sigma)}{\gamma+4\sigma\theta}$.

Finally, we derive the threshold $\underline{\alpha}_{cl}$. The condition can be re-expressed as $\alpha \leq \underline{\alpha}_{cl} = \frac{1-\gamma}{q_l^*} = \frac{(1-\gamma)(\gamma+4\sigma\theta)}{4\sigma\theta(y+\sigma-2\phi\sigma)}$. Thus, $\underline{\alpha}_{cl}$ increases as $\phi$ increases. Notice that if $\phi = 1$, dispute does not occur.

(b) Recall from previous analyses that if $\alpha > \underline{\alpha}_{cl}$, dispute occurs. Based on Equation (1.4), the platform's optimization problem is as follows:

$$\max_{f \geq 0} \quad h^*(q_l^*)\gamma p_l^* + f - \theta(k^* - y)^2,$$

$$\text{s.t.} \quad q_l^* - h^*(q_l^*)p_l^* - \phi q_l^* \geq 0, \tag{A.80}$$

$$-\alpha(q_l^*)^2 + h^*(q_l^*)(1-\gamma)p_l^* - f \geq 0, \tag{A.81}$$

where Equation (A.82) is the individual rationality constraint of the client and Equation (A.81) is the individual rationality constraint of the freelancer. Note that the analysis for the equilibrium outcome follows from the proof of Proposition 1.1. Thus, $\Pi$ is increasing in $f$ and the platform chooses the optimal $f$ such that both Equations (A.80) and (A.81) are binding, resulting in

$$\begin{aligned}
&(1-\phi)q_l^* - h^*(q_l^*)p_l^* = 0 \\
\Leftrightarrow\ &(1-\phi)q_l^* - \left(\frac{q_l^* - y + \sigma}{2\sigma} + \frac{\gamma p_l^*}{8\theta\sigma^2}\right)p_l^* = 0 \\
\Leftrightarrow\ &p_l^* = \frac{2\sigma\theta(2\alpha(y-\sigma) + (1-\gamma)(1-\phi))}{\gamma\alpha + (1-\gamma)\theta},
\end{aligned}$$

where the first step follows from $h^*(q_l^*) = \frac{q_l^* - y + \sigma}{2\sigma} + \frac{\gamma p_l^*}{8\theta\sigma^2}$ and the second step follows from $q_l^* = \frac{(1-\gamma)p_l^*}{4\alpha\sigma}$. Therefore, from $q_l^* = \frac{(1-\gamma)p}{4\sigma\alpha}$, we have

$$q_l^* = \frac{(1-\gamma)\theta(2\alpha(y-\sigma) + (1-\gamma)(1-\phi))}{2\alpha\left(\gamma\alpha + (1-\gamma)\theta\right)},$$

and

$$\begin{aligned}
f_l^* &= (1-\gamma)(1-\phi)q_l^* - \alpha(q_l^*)^2 \\
&= \frac{(1-\gamma)^2\theta(2\alpha(y-\sigma) + (1-\gamma)(1-\phi))(2\alpha(\gamma(1-\phi) - \theta(y-\sigma)) + (1-\gamma)\phi\theta)}{4\alpha(\gamma\alpha + (1-\gamma)\theta)^2}.
\end{aligned}$$

Therefore, the platform's utility is

$$
\begin{aligned}
\Pi_l^* =& h^*(q_l^*)\gamma p_l^* + f_l^* - \frac{\gamma^2 (p_l^*)^2}{16\theta\sigma^2} \\
=& \frac{q_l^* - y + \sigma}{2\sigma}\gamma p_l^* + f_l^* + \frac{\gamma^2 (p_l^*)^2}{16\theta\sigma^2} \\
=& \frac{1}{4\alpha(\gamma\alpha + (1-\gamma)\theta)^2}\Big[\theta(2\alpha(y-\sigma) + (1-\gamma)(1-\phi))\Big(-2\gamma^2\alpha^2(y-\sigma) \\
& + (1-\gamma)\alpha((2-\gamma)\gamma(1-\phi) - 2\gamma\sigma\theta - 2(1-\gamma)\theta y + 2\sigma\theta) \\
& + (1+\gamma)(1-\gamma)^2(1-\phi)\theta\Big)\Big].
\end{aligned}
$$

Moreover, since dispute fee has to be non-negative for contracting to occur, if $\sigma > y$, $f_l^* = 0$ at $\alpha = \frac{(1-\gamma)(1-\phi)}{2(\sigma-y)}$. If $\sigma \leq y - \frac{\gamma}{\theta}$, $f_l^* = 0$ at $\alpha = \frac{(1-\gamma)(1-\phi)\theta}{2(\theta(y-\sigma)-\gamma(1-\phi))}$. If $y - \frac{\gamma}{\theta} < \sigma \leq y$, $f_l^* \geq 0$ for all $\alpha$. Therefore, if dispute occurs, there exists a threshold, $\hat{\alpha}_{cl}$, such that $f_l^* \geq 0$ if and only if $\alpha \leq \hat{\alpha}_{cl}$, where $\hat{\alpha}_{cl}$ is given by

$$
\hat{\alpha}_{cl} = \begin{cases} \frac{(1-\gamma)(1-\phi)\theta}{2(\theta(y-\sigma)-\gamma(1-\phi))} & \text{if } \sigma \leq y - \frac{\gamma}{\theta}, \\ \infty & \text{if } y - \frac{\gamma}{\theta} < \sigma \leq y. \\ \frac{(1-\gamma)(1-\phi)}{2(2-\gamma)(\sigma-y)} & \text{if } \sigma > y. \end{cases}
$$

If $\alpha > \hat{\alpha}_{cl}$, since the dispute fee has to be non-negative, setting $f_l^* = 0$ would cause the individual rationality constraint of the freelancer to be violated. We define $\bar{\alpha}_{cl} = \max(\underline{\alpha}_{cl}, \hat{\alpha}_{cl})$. Contracting occurs if and only if $\alpha \leq \bar{\alpha}_{cl}$. Thus, given that contracting occurs, dispute occurs in equilibrium if and only if $\underline{\alpha}_{cl} < \alpha \leq \bar{\alpha}_{cl}$.

Finally, we compare the threshold where dispute does not occur to the main model. Comparing $\underline{\alpha}_{cl}$ with $\underline{\alpha}_c$, We have $\underline{\alpha}_{cl} - \underline{\alpha}_c = \frac{(1-\gamma)(\gamma+4\sigma\theta)}{4\sigma\theta(y+\sigma-2\phi\sigma)} - \frac{(1-\gamma)(\gamma+4\sigma\theta)}{4\sigma\theta(y+\sigma)} \geq 0$ and thus, $\underline{\alpha}_{cl} \geq \underline{\alpha}_c$. □

*Proof of Proposition 1.12* Proposition 1.12 can be proven by backward induction based on the decision tree in Figure 1.1.

The analysis for Stages 2 to 6 to obtain $q_l^+$ and $p_l^+$ respectively follows from the proof of Proposition 1.11 with $h^*(q)$ being replaced by $h^+(q)$ since the utilities of the freelancer and the client are similar. Thus, there exists a threshold $\underline{\alpha}_{dl}$ such that dispute does not occur if $\alpha \leq \underline{\alpha}_{dl}$ and dispute occurs if $\alpha > \underline{\alpha}_{dl}$. $q_l^+$ is then given by

$$q_l^+ = \begin{cases} \frac{p(y+\sigma)}{p+2\phi\sigma} & \text{if } \alpha \leq \underline{\alpha}_d, \\ \frac{(1-\gamma)p}{4\sigma\alpha} & \text{if } \alpha > \underline{\alpha}_d, \end{cases}$$

and $p_l^+ = \max(\frac{\alpha(q_l^+)^2}{1-\gamma}, \frac{f}{1-\gamma})$ if $\alpha \leq \underline{\alpha}_{dl}$, and

$$p_l^+ = \begin{cases} \hat{p}_{dl} & \text{if } f \leq \underline{f}_{dl}, \\ \frac{\underline{f}_d+\alpha(q_l^+)^2}{h^+(q_l^+)(1-\gamma)} & \text{if } f > \underline{f}_{dl}, \end{cases}$$

where $\hat{p}_{dl}$ is the solution to the unconstrained client's problem, and $\underline{f}_{dl}$ is the threshold such that $\hat{p}_{dl} = \frac{\underline{f}_{dl}+\alpha(q_l^+)^2}{h^+(q_l^+)(1-\gamma)}$.

At Stage 1, the platform chooses the dispute fee $f$ while satisfying the individual rationality constraints of the client and the freelancer.

(a) Recall from previous analyses that if $\alpha \leq \underline{\alpha}_{dl}$, dispute does not occur. The freelancer chooses quality $q_l^+ = \frac{p_l^+(y+\sigma)}{p_l^++2\phi\sigma}$ and the client offers price $p_l^+ = \max(\frac{\alpha(y+\sigma)^2}{1-\gamma}, \frac{f}{1-\gamma})$. Thus, the platform will achieve a utility of $\Pi(f) = \gamma p_l^+ = \gamma \max(\frac{\alpha(y+\sigma)^2}{1-\gamma}, \frac{f}{1-\gamma})$. Since $\Pi$ is increasing in $f$, we have

$$f_l^+ = (1-\gamma)(y+\sigma-2\phi\sigma),$$

and $p_l^+ = q_l^+ = y+\sigma-2\phi\sigma$. Hence, the platform's equilibrium utility is $\Pi_l^+ = \gamma(y+\sigma-2\phi\sigma)$. Consequently, following the proof of Proposition 1.3, $\underline{\alpha}_{dl} = \frac{1-\gamma}{y+\sigma-2\phi\sigma}$.

(b) Recall from previous analyses that if $\alpha > \underline{\alpha}_{dl}$, dispute occurs. Based on Equation (1.6), the platform's optimization problem is as follows:

$$\max_{f\geq 0} \quad h^+(q_l^+)\gamma p_l^+ + f,$$

$$\text{s.t.} \quad q_l^+ - h^+(q_l^+)p_l^+ - \phi q_l^+ \geq 0, \tag{A.82}$$

$$-\alpha(q_l^+)^2 + h^+(q_l^+)(1-\gamma)p_l^+ - f \geq 0, \tag{A.83}$$

where Equation (A.82) is the individual rationality constraint of the client and Equation (A.83) is the individual rationality constraint of the freelancer. Note that the analysis for the equilibrium outcome follows from the proof of Proposition 1.3. Thus, $\Pi$ is increasing in $f$ and the platform chooses the optimal $f$ such that both Equations (A.82) and (A.83) are binding, resulting in

$$p_l^+ = \frac{2\sigma(2\alpha(y-\sigma) + (1-\gamma)(1-\phi))}{1-\gamma},$$

and

$$q_l^+ = \frac{(1-\gamma)(1-\phi)}{2\alpha} + y - \sigma,$$

and

$$f_l^+ = \frac{(2\alpha(y-\sigma) + (1-\gamma)(1-\phi))(-2\alpha(y-\sigma) + (1-\gamma)(1-\phi))}{4\alpha}.$$

Therefore, the platform's utility is

$$\begin{aligned}\Pi_l^+ &= h^+(q_l^+)\gamma p_l^+ + f_l^+ \\ &= \frac{(2\alpha(y-\sigma) + (1-\gamma)(1-\phi))(-2\alpha(y-\sigma) + (1+\gamma)(1-\phi))}{4\alpha}.\end{aligned}$$

Moreover, since $f_l^+ \geq 0$ for contracting to occur, if $\sigma > y$, $f_l^+ = 0$ at $\alpha = \frac{(1-\gamma)(1-\phi)}{2(\sigma-y)}$. If $\sigma \leq y$, $f_l^+ = 0$ at $\alpha = \frac{(1-\gamma)(1-\phi)}{2(y-\sigma)}$. Therefore, if dispute occurs, there exists a threshold $\hat{\alpha}_{dl}$, which is the solution of $f_l^+ = q_l^+((1-\gamma)(1-\phi) - \hat{\alpha}_{dl}q_l^+) = 0$, such that $f_l^+ \geq 0$ if and only if $\alpha \leq \hat{\alpha}_{dl}$, where $\hat{\alpha}_{dl}$ is given by

$$\hat{\alpha}_{dl} = \begin{cases} \frac{(1-\gamma)(1-\phi)}{2(y-\sigma)} & \text{if } \sigma \leq y, \\ \frac{(1-\gamma)(1-\phi)}{2(\sigma-y)} & \text{if } \sigma > y. \end{cases}$$

If $\alpha > \hat{\alpha}_{dl}$, since the dispute fee has to be non-negative, setting $f^+ = 0$ would cause the individual rationality constraint of the freelancer to be violated. We define $\bar{\alpha}_{dl} = \max(\underline{\alpha}_{dl}, \hat{\alpha}_{dl})$. Contracting occurs in equilibrium if and only if $\alpha \leq \bar{\alpha}_{dl}$.

Thus, given that contracting occurs, dispute occurs in equilibrium if and only if $\underline{\alpha}_{dl} < \alpha \leq \bar{\alpha}_{dl}$.

Finally, we compare the threshold where dispute does not occur to the main model. Comparing $\underline{\alpha}_{dl}$ with $\underline{\alpha}_{d}$, We have $\underline{\alpha}_{dl} - \underline{\alpha}_{d} = \frac{1-\gamma}{y+\sigma-2\phi\sigma} - \frac{1-\gamma}{y+\sigma} \geq 0$ and thus, $\underline{\alpha}_{dl} \geq \underline{\alpha}_{d}$. □

*Proof of Theorem 1.10* Following Propositions 1.11 and 1.12, we first compare the $\alpha$ thresholds under the different dispute systems. Under the centralized dispute system, $\underline{\alpha}_{cl} = \frac{(1-\gamma)(\gamma+4\sigma\theta)}{4\sigma\theta(y+\sigma-2\phi\sigma)}$; under the decentralized dispute system, $\underline{\alpha}_{dl} = \frac{1-\gamma}{y+\sigma-2\phi\sigma}$. Thus, the difference between $\underline{\alpha}_{dl}$ and $\underline{\alpha}_{cl}$ is $\underline{\alpha}_{dl} - \underline{\alpha}_{cl} = \frac{1-\gamma}{y+\sigma-2\phi\sigma} - \frac{(1-\gamma)(\gamma+4\sigma\theta)}{4\sigma\theta(y+\sigma-2\phi\sigma)} \leq 0$. Hence, $\underline{\alpha}_{dl} \leq \underline{\alpha}_{cl}$. We next compare the $\alpha$ thresholds beyond which contracting does not occur between the centralized and decentralized dispute systems. Under the centralized dispute system, $\bar{\alpha}_{cl} = \max(\underline{\alpha}_{cl}, \frac{(1-\gamma)(1-\phi)\theta}{2(\theta(y-\sigma)-\gamma(1-\phi))})$ if $\sigma \leq y - \frac{\gamma}{\theta}$ and $\bar{\alpha}_{cl} \to \infty$ if $y - \frac{\gamma}{\theta} < \sigma \leq y$; under the decentralized dispute system, $\bar{\alpha}_{dl} = \max(\underline{\alpha}_{dl}, \frac{(1-\gamma)(1-\phi)}{2(y-\sigma)})$. If $y - \frac{\gamma}{\theta} < \sigma \leq y$, we can obtain $f_l^* \geq 0$ for all $\alpha$ under the centralized dispute system, and thus, $\bar{\alpha}_{cl} \geq \bar{\alpha}_{dl}$. If $\sigma \leq y - \frac{\gamma}{\theta}$, as we know from the above that $\underline{\alpha}_{dl} \leq \underline{\alpha}_{cl}$, we now compare the case where $\bar{\alpha}_{dl} = \frac{(1-\gamma)(1-\phi)}{2(y-\sigma)}$ with $\bar{\alpha}_{cl} = \frac{(1-\gamma)(1-\phi)\theta}{2(\theta(y-\sigma)-\gamma(1-\phi))}$. We obtain $\bar{\alpha}_{dl} - \bar{\alpha}_{cl} \geq 0$. Therefore, we have $\bar{\alpha}_{dl} \leq \bar{\alpha}_{cl}$.

We now compare the platform's equilibrium utilities between the centralized and decentralized dispute systems under the different regions of $\alpha$.

(a) If $\alpha \leq \underline{\alpha}_{dl}$, dispute does not occur under either system. In this case, under the centralized dispute system, $\Pi_l^* = \frac{4\gamma\sigma\theta(y+\sigma-2\phi\sigma)}{\gamma+4\sigma\theta}$; under the decentralized dispute system, $\Pi_l^+ = \gamma(y+\sigma-2\phi\sigma)$. Therefore, taking the difference $\Pi_l^+ - \Pi_l^*$, we have $\Pi_l^+ - \Pi_l^* = \frac{\gamma(y+\sigma-2\phi\sigma)}{\gamma+4\sigma\theta}$. Thus, $\Pi_l^+ \geq \Pi_l^*$ for $\phi \leq 1$.

(b) If $\underline{\alpha}_{dl} < \alpha \leq \underline{\alpha}_{cl}$, recall from Proposition 1.11 that $q_l^* = \frac{4\sigma\theta(y+\sigma-2\phi\sigma)}{\gamma+4\sigma\theta}$ and from Proposition 1.12 that $q_l^+ = \frac{(1-\gamma)(1-\phi)}{2\alpha} + y - \sigma$. It is easy to see that the difference $q_l^+ - q_l^*$ is decreasing in $\alpha$ as only $q_l^+$ is decreasing in $\alpha$. Taking the difference between the two quality levels at $\underline{\alpha}_{cl}$, we have $q_l^+ - q_l^* = \frac{\gamma(y-\sigma)+2(\phi-1)\sigma\theta((2\phi+3)\sigma-y)}{\gamma+4\sigma\theta} \geq 0$ if $\sigma \leq \frac{\sqrt{(\gamma+2(\phi-1)\theta y)^2-8\gamma\left(2\phi^2+\phi-3\right)\theta y}-\gamma+2(1-\phi)\theta y}{4\left(3-2\phi^2-\phi\right)\theta}$. Let $\bar{\sigma}_l = \frac{\sqrt{(\gamma+2(\phi-1)\theta y)^2-8\gamma\left(2\phi^2+\phi-3\right)\theta y}-\gamma+2(1-\phi)\theta y}{4\left(3-2\phi^2-\phi\right)\theta}$. Therefore, if $\sigma \leq \bar{\sigma}_l$, $q_l^+ \geq q_l^*$. Consequently, $\Pi_l^+ = h(q_l^+)\gamma p_l^+ + f_l^+ = \gamma q_l^+ + f_l^+ \geq \gamma q_l^* = \Pi_l^*$ as $q_l^+ - q_l^* \geq 0$. Thus, combining all cases, there exists a threshold $\bar{\alpha}_l$, where $\bar{\alpha}_l = \bar{\alpha}_{dl}$, such that $\Pi_l^+ \geq \Pi_l^*$ if and only if $\alpha \leq \bar{\alpha}_l$. □

APPENDIX B

**APPENDIX OF CHAPTER 2**

## B.1 Proofs

*Proof of Proposition 2.1* We use backward induction to analyze the equilibrium utility of a firm. We first derive the number of workers $x_{it}$ to adjust for each period after the total absenteeism is realized. et the total adjusted manpower be $x_t = m_t(h_t - H)$. From Equation (2.1), the firm solves the following maximization problem:

$$\max_{x_t} \; p\min[\lambda, \gamma_{it}L_i + x_{it}] - w\gamma_{it}L_i - x_{it}(w + c_1)\mathbf{1}_{x_{it}\geq 0} + x_{it}(w - c_2)\mathbf{1}_{x_{it}<0},$$

$$\text{s.t. } x_t \leq \gamma L_i, \tag{B.1}$$

where Equation (B.1) represents the available manpower constraint. From the above problem, it is easy to see that if $p - w - c_1 < 0$, $x_t = 0$. If $p - w - c_1 \geq 0$, then

$$x_{it} = \begin{cases} \lambda - \gamma_{it}L_i & \text{if } \frac{\lambda}{L_i} < \gamma_{it} \leq 1 \text{ (Cancelling some shifts)}, \\ \lambda - \gamma_{it}L_i & \text{if } \frac{\lambda}{2L_i} < \gamma_{it} \leq \frac{\lambda}{L_i} \text{ (Sufficient workers for adding shifts)}, \\ \gamma_{it}L_i & \text{if } \gamma_{it} \leq \frac{\lambda}{2L_i} \text{ (Insufficient workers for adding shifts)}. \end{cases}$$

Therefore, the realized firm's per period profit is given by

$$\pi_{it} = \begin{cases} [2(p - w) - c_1]\gamma_{it}L_i & \text{if } \gamma_{it} \leq \frac{\lambda}{2L_i}, \\ (p - w - c_1)\lambda + c_1\gamma_{it}L_i & \text{if } \frac{\lambda}{2L_i} < \gamma_{it} \leq \frac{\lambda}{L_i}, \\ (p - w + c_2)\lambda - c_2\gamma_{it}L_i & \text{if } \frac{\lambda}{L_i} < \gamma_{it} \leq 1, \end{cases} \tag{B.2}$$

and the total profit is given by $\Pi_i = -c_v\frac{L_i+\bar{L}}{M}L_i + \mathbb{E}[\sum_{t=1}^{\infty}\delta^t\pi_t]$. Since the firm always hire sufficient workers to meet the future demand, i.e., $L_i \geq \lambda$, to analyze the expected profit per period $\mathbb{E}[\pi_t]$, we take the expectation with respect to $\gamma_{it}$:

$$\begin{aligned}\mathbb{E}[\pi_{it}] &= \int_0^{\frac{\lambda}{2L_i}} [2(p-w)-c_1]\gamma L_i \,\mathrm{d}\gamma + \int_{\frac{\lambda}{2L_i}}^{\frac{\lambda}{L_i}} (p-w-c_1)\lambda + c_1\gamma L_i \,\mathrm{d}\gamma \\ &\quad + \int_{\frac{\lambda}{L_i}}^{1} (p-w+c_2)\lambda - c_2\gamma L_i \,\mathrm{d}\gamma \\ &= -\frac{\lambda(\lambda(c_1+p-w)+4L_i(w-p)) + 2c_2(\lambda-L_i)^2}{4L_i}. \end{aligned} \tag{B.3}$$

Therefore, the total expected firm's profit at period 0 is

$$\begin{aligned}\Pi_i &= -c_v\frac{L_i+\bar{L}}{M}L + \sum_{t=1}^{\infty}\delta^t\left(-\frac{\lambda(\lambda(c_1+p-w)+4L_i(w-p))+2c_2(\lambda-L_i)^2}{4L_i}\right) \\ &= -c_v\frac{L_i+\bar{L}}{M}L + \frac{\lambda(\lambda(c_1+p-w)+4L_i(w-p))+2c_2(\lambda-L_i)^2}{4L_i(1-\delta)},\end{aligned}$$

where the last step follows from $\sum_{t=1}^{\infty}\delta^t = \frac{1}{1-\delta}$. Thus, to decide on the number of workers $L$ to hire at period 0, we take the derivative of $\Pi_i$ with respect to $L_i$, which yields

$$\frac{\partial \Pi_i}{\partial L_i} = -\frac{\lambda^2 M(c_1+p-w) + 2c_2M\left(\lambda^2 - L_i^2\right) + 4c_v(\delta-1)L_i^2(2L+\bar{L})}{4(\delta-1)L_i^2M},$$

and the second derivative yields

$$\frac{\partial^2 \Pi_i}{\partial L_i^2} = \frac{\lambda^2(c_1+2c_2+p-w)}{2(\delta-1)L_i^3} - \frac{2c_v}{M} < 0.$$

Since $\frac{\partial^2\Pi_i}{\partial L_i^2} < 0$, $\Pi$ is concave in $L_i$ and the optimal $L_i^*$ is given by the first order condition below

$$\lambda^2 M(c_1+p-w) + 2c_2M\left(\lambda^2-(L_i^*)^2\right) + 4c_v(\delta-1)(L_i^*)^2(2L_i+\bar{L}) = 0. \tag{B.4}$$

As all the firms are homogeneous, $\bar{L} = L_i^*(N-1)$. Thus, from Equation (B.4), we have

$$\lambda^2 M(c_1+p-w) + 2c_2M\left(\lambda^2-(L_i^*)^2\right) + 4c_v(\delta-1)(L_i^*)^3(N+1) = 0. \tag{B.5}$$

Hence, $L_i^*$ is given by the solution of Equation (B.5).

Next, we derive some comparative statics for $L_i^*$. Differentiating Equation (B.5) with respect to $c_1$, we have

$$\frac{\partial L_i^*}{\partial c_1} = \frac{\lambda^2 M}{4L_i^*(c_2 M + 3c_v(1-\delta)(1+N)L_i^*)} > 0.$$

Differentiating Equation (B.5) with respect to $c_2$, we have

$$\begin{aligned}\frac{\partial L_i^*}{\partial c_2} &= \frac{M(\lambda^2 - (L_i^*)^2)}{2HL_i^*(c_2 M + 3c_v(1-\delta)(1+N)L_i^*)} \\ &= \frac{4c_v(1-\delta)(L_i^*)^3(N+1) - \lambda^2 M(c_1 + p - w)}{4HL_i^* c_2(c_2 M + 3c_v(1-\delta)(1+N)L_i^*)} \\ &< 0,\end{aligned}$$

where the second step follows from re-arranging the terms. Thus, $L_i^*$ is increasing in $c_1$ and decreasing in $c_2$. If $c_1 = c_2 = c$,

$$\frac{\partial L^*}{\partial c} = \frac{M\left(3\lambda^2 - 2(L^*)^2\right)}{4L^*(cM - 3c_v(\delta-1)L^*(N+1))}.$$

Thus, $L_i^*$ is increasing in $c$ if $3\lambda^2 \geq 2(L^*)^2$ and decreasing in $c$ otherwise. Differentiating Equation (B.5) with respect to $M$, we have

$$\begin{aligned}\frac{\partial L_i^*}{\partial M} &= \frac{\lambda^2(c_1 + 2c_2 + p - w) - 2c_2(L_i^*)^2}{4L_i^*(c_2 M - 3c_v(\delta-1)L^*(N+1))} \\ &= \frac{4c_v(1-\delta)(L_i^*)^3(N+1)}{4ML_i^*(c_2 M - 3c_v(\delta-1)L_i^*(N+1))} \\ &> 0,\end{aligned}$$

where the second step follows from re-arranging the terms. Note that since $\frac{\partial L_i^*}{\partial M} > 0$, there exists a threshold $\bar{M}$ such that $3\lambda^2 = 2(L_i^*)^2$ if $M \leq \bar{M}$ and $3\lambda^2 < 2(L_i^*)^2$ if $M > \bar{M}$. Therefore, $L_i^*$ is increasing in $c$ if and only if $M \leq \bar{M}$. □

*Proof of Proposition 2.2* Let $W_{wages}$ denotes the expected wages paid per period for a firm. From the proof of Proposition 2.1, we have

$$
\begin{aligned}
W_{wages} = &\int_{\frac{\lambda}{2L_i^*}}^{\frac{\lambda}{L_i^*}} ((c_1 + w)(\lambda - \gamma L_i^*) + \gamma L_i^* w) \, \mathrm{d}\gamma + \int_0^{\frac{\lambda}{2L_i^*}} (\gamma L_i^*(c_1 + w) + \gamma L_i^* w) \, \mathrm{d}\gamma \\
&+ \int_{\frac{\lambda}{L_i^*}}^{1} (\gamma L_i^* w - (w - c_2)(\gamma L_i^* - \lambda)) \, \mathrm{d}\gamma \\
= &\frac{\lambda(c_1\lambda + 4L_i^* w - \lambda w) + 2c_2(\lambda - L_i^*)^2}{4L_i^*},
\end{aligned}
$$

The expected wages earned by a worker in a single period is then given by $\mathbb{E}[u_{it}] = \frac{W_{wage}}{L_i^*} = \frac{\lambda(c_1\lambda + 4L_i^* w - \lambda w) + 2c_2(\lambda - L_i^*)^2}{4(L_i^*)^2}$. Therefore, we have

$$
\frac{\partial W_{wage}}{\partial L_i^*} = \frac{\lambda(2L_i^*(c_2 - w) + \lambda(w - 2c_2 - c_1))}{2(L_i^*)^3},
$$

which is negative if $w \leq 2c_2 + c_1$. Thus, $\frac{\partial W_{wage}}{\partial L_i^*} < 0$ if $w \leq 2c_2 + c_1$.

$$
\frac{\partial W_{wages}}{\partial c_1} = \frac{\partial W_{wages}}{\partial L_i^*} \frac{\partial L_i^*}{\partial c_1} - \frac{\lambda}{2(L_i^*)^3} < 0,
$$

where the last step follows from $\frac{\partial W_{wages}}{\partial L_i^*} < 0$ and $\frac{\partial L_i^*}{\partial c_1} > 0$ from Proposition 2.1. Moreover,

$$
\frac{\partial W_{wages}}{\partial c_2} = \frac{\partial W_{wages}}{\partial L_i^*} \frac{\partial L_i^*}{\partial c_2} + \frac{\lambda(2L_i^* - 2\lambda)}{2(L_i^*)^3} > 0,
$$

where the last step follows from $\frac{\partial W_{wages}}{\partial L_i^*} < 0$ and $\frac{\partial L_i^*}{\partial c_2} < 0$ from Proposition 2.1. Thus, the expected wages earned by a worker per period is decreasing in $c_1$ and increasing in $c_2$. In this case, if $c_1 = c_2 = c$,

$$
\frac{\partial W_{wages}}{\partial c} = \frac{2\lambda L_i'(2L_i^*(c - w) + \lambda(w - 3c)) + L_i^* \left(2(L_i^*)^2 - 3\lambda^2\right)}{4(L_i^*)^3}, \tag{B.6}
$$

where $L_i'$ is the derivative of $L_i^*$ with respect to $c$. Since $L_i'$ is positive if and only if $3\lambda^2 \geq 2(L^*)^2$, if $w \leq 3c$, Equation (B.6) is negative if and only if $3\lambda^2 \geq 2(L^*)^2$. Therefore, $W_{wages}$ is decreasing in $c$ if and only if $M \leq \bar{M}$. □

# BIBLIOGRAPHY

Aaronson D, French E (2007) Product market evidence on the employment effects of the minimum wage. *Journal of Labor Economics* 25(1):167–200.

Aaronson D, French E, MacDonald J (2008) The minimum wage, restaurant prices, and labor market structure. *The Journal of Human Resources* 43(3):688–720.

Ahuja K, Chandra V, Lord V, Peens C (2021) Ordering in: The rapid evolution of food delivery. *McKinsey & Company* (September, 22), `https://tinyurl.com/yc42z8y4`.

Allon G, Cohen MC, Sinchaisri WP (2023) The impact of behavioral and economic drivers on gig economy workers. *Manufacturing & Service Operations Management* Forthcoming.

Aloisi A (2016) Commoditized workers: Case study research on labor law issues arising from a set of on-demand/gig economy platforms. *Comparative Labor Law and Policy Journal* 37(3):653–690.

Bai J, So KC, Tang CS, Chen XM, Wang H (2019) Coordinating supply and demand on an on-demand service platform with impatient customers. *Manufacturing & Service Operations Management* 21(3):556–570.

Baker G, Gibbons R, Murphy KJ (1994) Subjective performance measures in optimal incentive contracts. *The Quarterly Journal of Economics* 109(4):1125–1156.

Banker RD, Khosla I, Sinha KK (1998) Quality and competition. *Management Science* 44(9):1179–1192.

Baron DP (1994) Electoral competition with informed and uniformed voters. *American Political Science Review* 88(1):33–47.

Battigalli P, Dufwenberg M (2007) Guilt in games. *American Economic Review* 97(2):170–176.

Battigalli P, Dufwenberg M (2009) Dynamic psychological games. *Journal of Economic Theory* 144(1):1–35.

Belavina E, Marinesi S, Tsoukalas G (2020) Rethinking crowdfunding platform design: Mechanisms to deter misconduct and improve efficiency. *Management Science* 66(11):4980–4997.

Benjaafar S, Ding JY, Kong G, Taylor T (2022) Labor welfare in on-demand service platforms. *Manufacturing & Service Operations Management* 24(1):110–124.

Benjaafar S, Hu M (2020) Operations management in the age of the sharing economy: What is old and what is new? *Manufacturing & Service Operations Management* 22(1):93–101.

Benjaafar S, Kong G, Li X, Courcoubetis C (2019) Peer-to-peer product sharing: Implications for ownership, usage, and social welfare in the sharing economy. *Management Science* 65(2):477–493.

Bernstein F, DeCroix GA, Keskin NB (2021) Competition between two-sided platforms under demand and supply congestion effects. *Manufacturing & Service Operations Management* 23(5):1043–1061.

Bidwell K, Casey K, Glennerster R (2020) Debates: Voting and expenditure responses to political communication. *Journal of Political Economy* 128(8):2880–2924.

Breese E (2023) Uber Eats and Bolt ranked UK's worst gig economy companies for working conditions. *Big Issue* (April, 28), `https://tinyurl.com/m48pvzpu`.

Burbano VC, Chiles B (2022) Mitigating gig and remote worker misconduct: Evidence from a real effort experiment. *Organization Science* 33(4):1273–1299.

Cachon GP, Daniels KM, Lobel R (2017) The role of surge pricing on a service platform with self-scheduling capacity. *Manufacturing & Service Operations Management* 19(3):368–384.

Cameron LD, Rahman H (2022) Expanding the locus of resistance: Understanding the co-constitution of control and resistance in the gig economy. *Organization Science* 33(1):38–58.

Card D, Krueger AB (2000) Minimum wages and employment: A case study of the fast-food industry in New Jersey and Pennsylvania: Reply. *The American Economic Review* 90(5):1397–1420.

Carlsson H, van Damme E (1993) Global games and equilibrium selection. *Econometrica* 61(5):989–1018.

Chakraborty S, Ma A, Swinney R (2023) Designing rewards-based crowdfunding campaigns for strategic (but distracted) contributors. *Naval Research Logistics* 70(1):3–20.

Chakraborty S, Swinney R (2019) Signaling to the crowd: Private quality information and rewards-based crowdfunding. *Manufacturing & Service Operations Management* 23(1):1–266.

Chen FG (2017) Facts about disputes [Discussion post]. `https://tinyurl.com/bdbeejs5`.

Chen K (2022) Catching up to a new normal: The effects of shifting industry standards on contract interpretation. *Fordham Law Review* 90(6):2839–2868.

Chen L, Cui Y, Liu J, Liu X (2022a) Bonus competition in the gig economy. Working Paper, `https://ssrn.com/abstract=3392700`.

Chen M, Hu M, Wang J (2022b) Food delivery service and restaurant: Friend or foe? *Management Science* 68(9):6539–6551.

Chen MK (2016) Dynamic pricing in a labor market: Surge pricing and flexible work on the uber platform. *Proceedings of the 2016 ACM Conference on Economics and Computation*, 455, EC '16 (New York, NY, USA: Association for Computing Machinery).

Chen X, Li Z, Ming L, Zhu W (2022c) The incentive game under target effects in ridesharing: A structural econometric analysis. *Manufacturing & Service Operations Management* 24(2):972–992.

Chris (2021) Have any other freelancers been let down by PPHs dispute system? [Discussion post]. `https://tinyurl.com/4jfxed2e`.

Chuang HHC, Oliva R, Perdikaki O (2016) Traffic-based labor planning in retail stores. *Production and Operations Management* 25(1):96–113.

Claussen J, Khashabi P, Kretschmer T, Seifried M (2018) Knowledge work in the sharing economy: What drives project success in online labor markets? Working Paper, https://ssrn.com/abstract=3102865.

Cohen RM (2022) The coming fight over the gig economy, explained . *Vox* (October, 12), https://tinyurl.com/yck49zub.

Cordina JP (2022) Bolt dismissing self-employed couriers in favour of work agency staff. *Newsbook* (December, 13), https://tinyurl.com/48fxadbc.

CryptoTask (2022) Expanding the potential of the freelancing market through blockchain-related advantages. Retrieved Dec 18, https://www.cryptotask.org/en/info.

Dai H, Swaminathan JM, Xu Y (2022) Leveraging the experience: Exploration and exploitation in gig worker learning process. Working Paper, https://ssrn.com/abstract=4106978.

Dawande M, Janakiraman G, Qi A, Wu Q (2019) Optimal incentive contracts in project management. *Production and Operations Management* 28(6):1431–1445.

Deb J, Li J, Mukherjee A (2016) Relational contracts with subjective peer evaluations. *The RAND Journal of Economics* 47(1):3–28.

DeVault IA, Figueroa M, Kotler FB, Maffie M, Wu J (2019) On-demand platform workers in New York State: The challenges for public policy. (The Worker Institute, New York).

Dube A, Lester TW, Reich M (2010) Minimum wage effects across state borders: Estimates using contiguous counties. *The Review of Economics and Statistics* 92(4):945–964.

Dunn G, Manzo F, Petrucci L, Bruno R (2022) Implementing a fair workweek law in illinois: Protecting frontline workers from unpredictable schedules. Report, https://tinyurl.com/yckvzkb4.

Edmond C (2013) Information manipulation, coordination, and regime change. *The Review of Economic Studies* 80(4):1422–1458.

Elmaghraby WJ (2000) Supply contract competition and sourcing policies. *Manufacturing & Service Operations Management* 2(4):350–371.

Ernst A, Jiang H, Krishnamoorthy M, Sier D (2004) Staff scheduling and rostering: A review of applications, methods and models. *European Journal of Operational Research* 153(1):3–27.

Ethearnal (2021) Ethearnal whitepaper version 1.0. Retrieved July 8, `https://ethearnal.com/ethearnal-whitepaper.pdf`.

Falk A, Fischbacher U (2006) A theory of reciprocity. *Games and Economic Behavior* 54(2):293–315.

Feddersen T, Pesendorfer W (1998) Convicting the innocent: The inferiority of unanimous jury verdicts under strategic voting. *American Political Science Review* 92(1):23–35.

Feldman P, Frazelle AE, Swinney R (2023) Managing relationships between restaurants and food delivery platforms: Conflict, contracts, and coordination. *Management Science* 69(2):812–823.

Fisher M, Gallino S, Netessine S (2021) Setting retail staffing levels: A methodology validated with implementation. *Manufacturing & Service Operations Management* 23(6):1562–1579.

Fisher M, Krishnan J, Netessine S (2006) Retail store execution: An empirical study. Working Paper, `https://ssrn.com/abstract=2319839`.

Grossman GM, Helpman E (1996) Electoral competition and special interest politics. *The Review of Economic Studies* 63(2):265–286.

Guda H, Subramanian U (2019) Your uber is arriving: Managing on-demand workers through surge pricing, forecast communication, and worker incentives. *Management Science* 65(5):1995–2014.

Ha A, Long X, Nasiry J (2016) Quality in supply chain encroachment. *Manufacturing & Service Operations Management* 18(2):280–298.

Harknett K, Schneider D, Irwin V (2021) Seattle's secure scheduling ordinance:

Year 2 worker impact report. Report, https://shift.hks.harvard.edu/wp-content/uploads/2021/02/Seattle-Year-2-Evaluation.pdf.

Hawkins WB (2015) Bargaining with commitment between workers and large firms. *Review of Economic Dynamics* 18(2):350–364.

He EJ, Goh J (2022) Profit or growth? dynamic order allocation in a hybrid workforce. *Management Science* 68(8):5891–5906.

Herman J (2017) Platform companies are becoming more powerful – but what exactly do they want? *International New York Times* (March, 21), https://nyti.ms/3zSr2l7.

Horton JJ, Chilton LB (2010) The labor economics of paid crowdsourcing. *Proceedings of the 11th ACM Conference on Electronic Commerce*, 209–218, EC '10 (New York, NY, USA: Association for Computing Machinery).

Hu B, Hu M, Zhu H (2022) Surge pricing and two-sided temporal responses in ride-hailing. *Manufacturing & Service Operations Management* 24(1):91–109.

Hu M, Zhou Y (2020) Price, wage and fixed commission in on-demand matching. Working Paper, https://ssrn.com/abstract=2949513.

Hu W (2022) Inside the fight to pay food delivery workers $23 an hour. *The New York Times* (December, 8), https://www.nytimes.com/2022/12/08/nyregion/nyc-food-delivery-workers-wage-increase.html.

Hyve (2023) Hyve & hyve protocol - A decentralized autonomous task marketplace. Retrieved January 8, https://hyve.works/static/media/whitepaper.cf4ae242.pdf.

Jarman D (2020) How similar is each state to every other? Daily kos elections' state similarity index will tell you. *Daily Kos* (February, 19), https://tinyurl.com/mryb8y6w.

Jin C, Hosanagar K, Veeraraghavan SK (2022) Do ratings cut both ways? Impact of bilateral ratings on platforms. Working Paper, https://ssrn.com/abstract=3066988.

Jones JM (2023a) The most similar state to every us state, according to chatgpt. *Objective Lists* (April, 16), https://tinyurl.com/tvz52nzh.

Jones JM (2023b) The most similar states to oregon. *Objective Lists* (February, 14), https://tinyurl.com/3hbz56ba.

Kamalahmadi M, Yu Q, Zhou YP (2021) Call to duty: Just-in-time scheduling in a restaurant chain. *Management Science* 67(11):6751–6781.

Kantor J (2014) Working anything but 9 to 5. *New York Times* (August, 13), https://tinyurl.com/sxmffbpr.

Katz LF, Krueger AB (2019) The rise and nature of alternative work arrangements in the United States, 1995–2015. *ILR Review* 72(2):382–416.

Kesavan S, Lambert SJ, Williams JC, Pendem PK (2022) Doing well by doing good: Improving retail store performance with responsible scheduling practices at the gap, inc. *Management Science* , ePub ahead of print March 2, https://doi.org/10.1287/mnsc.2021.4291.

Kojima F, Takagi Y (2010) A theory of hung juries and informative voting. *Games and Economic Behavior* 69(2):498–502.

Kudoh N, Miyamoto H, Sasaki M (2019) Employment and hours over the business cycle in a model with search frictions. *Review of Economic Dynamics* 31:436–461.

Kwan A, Yang SA, Zhang AH (2023) Crowd-judging on two-sided platforms: An analysis of in-group bias. *Management Science* Forthcoming.

Levin J (2003) Relational incentive contract. *American Economic Review* 93(3):835–857.

Liang C, Hong Y, Gu B (2016) Effects of IT-enabled monitoring systems in online labor markets. *2016 International Conference on Information Systems, ICIS 2016* (Association for Information Systems).

Littman J (2021) Why aren't restaurant workers coming back? Here's what the data shows. *Restaurant Dive* (September, 8), https://tinyurl.com/3ucc6aat.

Liu S, He L, Max Shen ZJ (2021) On-time last-mile delivery: Order assignment with travel-time predictors. *Management Science* 67(7):4095–4119.

Liu Y, Lou B, Zhao X, Li X (2023) Unintended consequences of advances in matching technologies: Information revelation and strategic participation on gig-economy platforms. *Management Science* Forthcoming.

Lu SF, Lu LX (2017) Do mandatory overtime laws improve quality? staffing decisions and operational flexibility of nursing homes. *Management Science* 63(11):3566–3585.

Mai Y, Hu B, Pekeč S (2023) Courteous or crude? Managing user conduct to improve on-demand service platform performance. *Management Science* 69(2):996–1016.

Mani V, Kesavan S, Swaminathan JM (2015) Estimating the impact of understaffing on sales and profitability in retail stores. *Production and Operations Management* 24(2):201–218.

Marinesi S, Girotra K (2013) Information acquisition through customer voting systems. Working Paper, `https://ssrn.com/abstract=2191940`.

Marion J (2018) Why the service industry is hard on your mental health. *Baltimore* (July, 11), `https://www.baltimoremagazine.com/section/fooddrink/why-the-service-industry-is-hard-on-your-mental-health/`.

Miller CC (2019) How unpredictable work hours turn families upside down. *New York Times* (October, 23), `https://www.nytimes.com/2019/10/16/upshot/unpredictable-job-hours.html`.

Morris S, Shin HS (1998) Unique equilibrium in a model of self-fulfilling currency attacks. *American Economic Review* 88(3):587–597.

Munhoz DA, Rainey R (2023) House republicans take up gig worker issues ahead of su hearing. *Bloomberg Law* (April, 12), `https://tinyurl.com/2y5pjkym`.

Musalem A, Olivares M, Schilkrut A (2021) Retail in high definition: Monitoring customer assistance through video analytics. *Manufacturing & Service Operations Management* 23(5):1025–1042.

Netessine S, Fisher M, Krishnan J (2010) Labor planning, execution, and retail store performance: An exploratory investigation. Working Paper, `https://ssrn.com/abstract=2319863`.

Neumark D, Wascher W (2000) Minimum wages and employment: A case study of the fast-food industry in new jersey and pennsylvania: Comment. *The American Economic Review* 90(5):1362–1396.

NYC (2021) Department of consumer and worker protection settles fair workweek cases with fast food franchisees. *City of New York* (July, 29), `https://tinyurl.com/5n9xtwhy`.

Ortolani P (2015) Self-enforcing online dispute resolution: Lessons from bitcoin. *Oxford Journal of Legal Studies* 36(3):595–629.

Papanastasiou Y, Yang SA, Zhang AH (2022) Improving dispute resolution in two-sided platforms: The case of review blackmail. *Management Science* Forthcoming.

Perdikaki O, Kesavan S, Swaminathan JM (2012) Effect of traffic on sales and conversion rates of retail stores. *Manufacturing & Service Operations Management* 14(1):145–162.

Rasheed R (2021) AMA with cryptotask. *Medium* (July 20), `https://tinyurl.com/ye2ydmda`.

Reyes JF (2021) Philadelphia makes target pay workers $22,000 for violating city's fair workweek law. *The Philadelphia Inquirer* (September, 28), `https://www.inquirer.com/news/target-fair-workweek-violation-philadelphia-20210902.html`.

Roels G, Corbett CJ (2021) Too many meetings? Scheduling rules for team coordination. Working Paper, `https://ssrn.com/abstract_id=3929502`.

Rowe G, Wright G (2001) Differences in expert and lay judgments of risk: Myth or reality? *Risk Analysis* 21(2):341–356.

Rundlett A, Svolik MW (2016) Deliver the vote! Micromotives and macrobehavior in electoral fraud. *American Political Science Review* 110(1):180–197.

Saad AT (2021) Factors affecting online food delivery service in Bangladesh: an empirical study. *British Food Journal* 123(2):535–550.

Schaarschmidt T (2017) When power turns toxic. *Scientific American* (May

1), https://https://www.scientificamerican.com/article/when-power-turns-toxic/.

Scheiber N (2021) Chipotle is sued by New York City over scheduling practices. *New York Times* (April, 28), https://www.nytimes.com/2021/04/28/business/chipotle-new-york-illegal-scheduling.html.

Schneider D, Harknett K (2019) Consequences of routine work-schedule instability for worker health and well-being. *American Sociological Review* 84(1):82–114.

Shevchuk A, Strebkov D (2018) Safeguards against opportunism in freelance contracting on the internet. *British Journal of Industrial Relations* 56(2):342–369.

Silver N (2008) State similarity scores. *FiveThirtyEight* (July, 7), https://fivethirtyeight.com/features/state-similarity-scores/.

Sterling T (2023) Just Eat to move entirely to self-employed 'gig worker' model in britain . *Reuters* (March, 21), https://shorturl.at/bmxOU.

Taylor CR, Yildirim H (2011) Subjective performance and the value of blind evaluation. *The Review of Economic Studies* 78(2):762–794.

Taylor TA (2018) On-demand service platforms. *Manufacturing & Service Operations Management* 20(4):704–720.

Torry H (2022) Omicron wave drives surge of workers calling in sick, working through illness. *The Wall Street Journal* (January, 23), https://tinyurl.com/5bkx6a3s.

Trejo SJ (1991) The effects of overtime pay regulation on worker compensation. *The American Economic Review* 81(4):719–740.

Trejo SJ (1993) Overtime pay, overtime hours, and labor unions. *Journal of Labor Economics* 11(2):253–278.

Tsoukalas G, Falk HB (2020) Token weighted crowdsourcing. *Management Science* 66(9):3799–4358.

Tzezana R (2015) What happens when you go into a dispute with fiverr? Or: the future of justice systems. (October 25), https://curatingthefuture.com/2015/10/25/fiverr_dispute_justice_systems/.

Ulmer MW, Thomas BW, Campbell AM, Woyak N (2021) The restaurant meal delivery problem: Dynamic pickup and delivery with deadlines and random ready times. *Transportation Science* 55(1):75–100.

Upwork (2020) Upwork's fourth annual future workforce report reveals accelerated adoption of independent and remote work amid COVID-19. (June 11), https://www.upwork.com/i/future-workforce/fw/2020/.

Van den Bergh J, Beliën J, De Bruecker P, Demeulemeester E, De Boeck L (2013) Personnel scheduling: A literature review. *European Journal of Operational Research* 226(3):367–385.

Van Huyck JB, Wildenthal JM, Battalio RC (2002) Tacit cooperation, strategic uncertainty, and coordination failure: Evidence from repeated dominance solvable games. *Games and Economic Behavior* 38(1):156–175.

Wang X, Cho SH, Scheller-Wolf A (2021) Green technology development and adoption: Competition, regulation, and uncertainty—A global game approach. *Management Science* 67(1):201–219.

Xu F, Zhang F (2018) Crowdfunding under social learning and network externalities. Working Paper, https://ssrn.com/abstract=3115891.

Xu Y, Lu B, Ghose A, Dai H, Zhou W (2023) The interplay of earnings, ratings, and penalties on sharing platforms: An empirical investigation. *Management Science* Forthcoming.

Yu Q, Mankad S, Shunko M (2022) Evidence of the unintended labor scheduling implications of the minimum wage. *Manufacturing & Service Operations Management* Forthcoming.