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Platform Exploitation in the Sharing Economy

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Abstract

We model a revenue sharing contract between a sharing economy platform and a freelance service provider, where the latter hides revenue from the former by canceling some assignments and performing them for cash ("platform exploitation"). The platform counters this via costly, imperfect audits with endogenous success probability, and a variable payment. We show that at equilibrium, all agent types except the highest, indulge in revenue falsification. This problem is exacerbated by the principal's ability to extract restitution from the agent.

Keywords: Platform exploitation; sharing economy; contract theory; optimal control

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1 Introduction

The sharing economy provides both consumer goods and services, and freelance employment to millions worldwide, and has attracted the attention of researchers on various aspects, including pricing and worker incentives [7], matching policies [13], demand management [5] and much more.

In a comprehensive review, [1] identify three canonical platform types in the sharing economy: (a) peer-to-peer resource sharing with complex interactions between demand and supply sides, (b) on-demand service platforms which match consumers and providers, and (c) on-demand rentals where the service provider is a single firm rather than freelancers like the other two.

The domain of our own model focuses on the first two types of applications described by [1], where freelance agents provide goods and services to customers. Several factors drive the survival and profitability of such sharing economy platforms, including network effects, trust and "disintermediation"—a phenomenon where freelancers and customers meet on the platform, but then defect and conduct further business off it [8]. A variant of this disintermediation phenomenon has recently been termed "platform exploitation" by [16], where freelance service providers utilize the platform's matching services, but then proceed to "cancel" the assignment, thus avoiding a revenue sharing agreement, and instead performing the service off the books, for cash.

[16]'s empirical study focuses on a Chinese healthcare platform that connects patients to freelance nurses who provide in-home care. In such a scenario, the freelancer can develop a long-term relationship with the customer, using the platform for initial lead generation. Thus, a nurse who initially shares revenue with the platform, has incentives to defect and do direct transactions with the same patient in future. This form of exploitation is also possible in scenarios like home maintenance, long term home rentals, freelance office work, etc.

However, there are certain scenarios like ride sharing, short term vacation rentals and customer-to-customer sales of goods, where platform exploitation occurs in the first transaction itself, and future freelancer-customer relationships may not be possible to form because of the *ad hoc* nature of the transaction. To illustrate this particular example of platform exploitation, consider the following uncomfortable situations many customers have faced, listed in the FAQs quoted below:

- [**Uber:** https://ubr.to/3wAtYib] "*My driver asked to be paid in cash:* If your driver requested cash even though you selected a cashless payment option, please let us know here within 30 days of the trip ending."
- [**Airbnb:** https://bit.ly/3vzdGVo] "*What should I do if someone asks me to pay outside of the Airbnb website?* If you've paid for your reservation outside of Airbnb (e.g. a bank transfer), you may have paid for a fraudulent reservation. To get help, let us know immediately."
- [**eBay:** https://ebay.to/2Ub5a2h] "*Offering to buy or sell outside of eBay policy:* Contacting another eBay member to discuss moving a purchase off eBay exposes both the buyer and seller to the risk of fraud. It also means both buyer and seller are not covered by our protection programs. [...] Activity that doesn't follow eBay policy could result in a range of actions including canceling listings, hiding or demoting all listings from search results, blocking some or all of your messages/communication with other members, lowering seller rating, buying or selling restrictions, account suspension, application of fees, and recovery of expenses for policy monitoring and enforcement. All fees paid or payable in relation to listings or accounts on which we take any action will not be refunded or otherwise credited to your account."

In each of the above cases, a freelancer (agent) attempts to bypass a revenue sharing contract with a platform (principal) and pockets the entire revenue for himself, resulting in loss of revenue to the platform. The agent exploits an information asymmetry and under-reports realized revenue to the platform. Naturally, platforms react by implementing various audit, penalty and even variable payment mechanisms to curtail platform exploitation. To understand platform exploitation (and thus curtail it), it is important to understand it from the first principles of agent incentives. We therefore draw from analogous scenarios in sharecropping [3], tax avoidance [4, 15], pollution levies [9], supplier audits [14] and retail theft [11].

In this paper, we model platform exploitation in a contract-theoretic setting where the platform (principal) is aware of the freelancer's (agent's) incentives to under-report revenue. A risk-neutral platform (principal) and a risk-neutral freelancer (agent) enter a revenue-sharing contract in which the freelancer may under-report true revenue (agent type). To detect this, the platform puts effort to conduct a costly but imperfect audit (mystery customers, encouraging customers to report malpractices etc.). Higher audit effort leads to increased probability of fraud detection which results in damages to the freelancer that escalate with the magnitude of revenue hidden. Part of this is recovered by the platform as penalties, while the rest represent reputational damages.

We show that the optimal contract features faking by all except the highest agent type. Further, we demonstrate that the endogenous audit effort and faking level are independent of the fraction of revenue-sharing specified in the contract. However, the principal expends more effort when it can recoup more penalties from the agent. Counter-intuitively, this leads to even higher under-reporting of revenue by the agent. Our analytical results are useful to platform operators in understanding platform exploitation—which is not yet well understood—from first principles.

2 Model

In this section we model the interaction between a platform (principal) and a freelancer (agent) in a contract-theoretic setting and derive equilibrium conditions for the optimal revenue-reporting function for the freelancer, and the optimal variable payment schedule for the principal.

2.1 Revenue sharing with variable payment

Consider a risk-neutral principal and a risk-neutral agent. The agent has done business worth x dollars (type) with a customer via the platform, and must share revenue with it as per a pre-decided, exogenous fraction α. He may under-report revenue—his private information—to the platform, but never over-reports it. Let this reported value be the function $u(x) \leq x$ that is endogenously determined at equilibrium.

We assume that the agent can under-report revenue at no cost to himself but can be caught by an audit conducted by the platform. Like [14], we model audit effort by the type-independent endogenous probability—denoted by $\gamma > 0$—of a successful audit. Like [14], we rule out uninteresting equilibria with zero audit effort by the principal. The audit cost function is $h(\gamma)$ and we assume that (i) $h(0) = 0$, (ii) $h'(\gamma) > 0$ and (iii) $h''(\gamma) > 0$.

If caught, the agent incurs an expected penalty $\gamma c(x - u(x))$, where $c(\cdot)$ is an exogenous penalty function commensurate with the level of fraud. We make the following assumptions about this penalty function: (i) $c(0) = 0$: no misreporting entails no penalty; (ii) $c'(0) = 0$: no misreporting leads to the minimum penalty; (iii) $c'(z) > 0 \; \forall z > 0$: penalty increases with the level of misreporting; and (iv) $c''(z) > 0 \; \forall z \geq 0$: the rate of penalty increase grows with the degree of misreporting.

This penalty includes the restitution $\delta c(x - u(x))$ collected by the platform and reputational damages $(1 - \delta)c(x - u(x))$ incurred by the freelancer, where $0 < \delta < 1$ is an exogenous constant. Thus the expected restitution that a principal can reclaim on a successful audit is $\gamma\delta c(x - u(x))$. This is similar to [4], but we endogenize the audit effort γ (probability of success) while they assume it to be exogenous.

Sharing economy platforms often include a variable payment to the agent, along with the usual revenue sharing component. While actual bonuses are conditioned on the reported revenue $u(x)$, we invoke the revelation principle [12] to look at only direct mechanisms. Thus, let $v(x)$ denote the variable payment to a freelancer. We make a further assumption that the agent cannot inflate the revenue x, which is reasonable given sufficient analytics mechanisms to detect fake trips to claim higher bonuses.

The true revenue x is private information to the freelancer. The platform, however, knows that it is distributed continuously between $[x_L, x_H]$ according to the probability density $f(x)$ and cumulative distribution $F(x)$. Thus, the principal's payoff is:

$$\Pi(\gamma, u(x), v(x)) = \alpha u(x) + \gamma\delta c(x - u(x)) - h(\gamma) - v(x) \tag{1}$$

We note that the above specification is functionally equivalent to the most general form of a revenue sharing contract, as in [2]. Similarly, the agent's payoff function is:

$$Y(\gamma, u(x), v(x), x) = x - \alpha u(x) - \gamma c(x - u(x)) + v(x) \tag{2}$$

The principal's objective is to maximize expected payoff:

$$\max_{\gamma, u(x), v(x)} \int_{x_L}^{x_H} \Pi(\gamma, u(x), v(x)) f(x) dx \tag{3}$$

subject to constraints on the agent's payoff as discussed above.
Incentive compatibility (IC) for the agent dictates that

$$\frac{dY}{dx} = \frac{\partial Y}{\partial x} \tag{4}$$

and individual rationality (IR) implies that

$$Y \geq 0 \tag{5}$$

Thus the principal's optimization program is (3) subject to IC (4) and IR (5) leading to the Hamiltonian:

$$\mathbb{H} = \Pi f + \lambda(x) Y_x + \mu Y \tag{6}$$

Further, in line with [3], we assume that the penalty function satisfies:

$$c' < 1 \tag{7}$$

so that $Y_x > 0$, and hence $\mu = 0$, leading to a slack IR. Note that $Y_x > 0$ is actually satisfied by $c' < 1/\gamma$, but we use the more restrictive specification (7) to avoid conditioning on an endogenous outcome γ. Under these conditions, we can solve for the optimal contract.

Proposition 1. *The optimal contract satisfies:*

$$h'(\gamma) = \int_{x_L}^{x_H} \delta c(x - u(x)) f(x) dx \tag{8}$$

$$\lambda(x) = -(1 - F(x)) \tag{9}$$

$$\frac{c'(x - u(x))}{c''(x - u(x))} = \left(\frac{1 - F(x)}{f(x)}\right) \cdot \frac{1}{(1 - \delta)} \tag{10}$$

$$v(x) = \alpha u(x) - x + \gamma c(x - u(x)) + \int_{x_L}^{x} [1 - \gamma c'(t - u(t)] \, dt \tag{11}$$

Proof. As γ is type-independent and $\mu = 0$, it is the solution of:

$$\max_{\gamma} \int_{x_L}^{x_H} \Pi(\gamma, u(x)) f(x) dx$$

Differentiating (3) with respect to γ and equating to zero yields (8). To solve for $\lambda(x), u(x)$, we first rewrite the Hamiltonian as:

$$\mathbb{H} = [x - h(\gamma) - \gamma(1 - \delta)c - Y] \, f + \lambda \, [1 - \gamma c'] \tag{12}$$

The first Pontryagin condition $d\lambda/dx = -\partial\mathbb{H}/\partial Y$, coupled with the transversality condition $\lambda(x_H) = 0$ yields (9). Substituting this result into the second Pontryagin condition $\partial\mathbb{H}/\partial u = 0$ yields (10). To solve for the optimal bonus $v(x)$, we note that

$$\frac{dY}{dt} = 1 - \gamma c'(t - u(t))$$

and thus,

$$Y = \int_{x_L}^{x} [1 - \gamma c'(t - u(t)] \, dt$$

Substituting (2) on the left and rearranging yields (11). □

Implementability and sufficiency

We now introduce additional conditions for the contract to be implementable, i.e., the necessary monotonicity condition $u' > 0$, which leads to the reporting function $u(x)$ being invertible in $[x_L, x_H]$ [4, 6, chapter 7].

Lemma. *Either of the two conditions below is sufficient to ensure that the equilibrium reporting function is monotonically increasing and therefore invertible in* $[x_L, x_H]$*, i.e.* $u' > 0$:

$$\Theta' > 0 \quad \text{and} \quad c''' \leq 0 \tag{13}$$

$$\Theta' > 0 \quad \text{and} \quad c''' > 0 \quad \text{and} \quad c'''' \leq 0 \tag{14}$$

where $\Theta(x) \equiv f(x)/[1 - F(x)]$ *is the hazard function.*

Proof. Differentiating both sides of (10) with respect to x and rearranging terms, we obtain:

$$\frac{[(c'')^2 - c'c''']}{(c'')^2} \cdot u' = \frac{[(c'')^2 - c'c''']}{(c'')^2} + \frac{1}{(1-\delta)} \cdot \frac{\Theta'}{\Theta^2}$$

From the above expression, it is easy to infer that $\Theta' > 0$ and $(c'')^2 - c'c''' > 0$ are sufficient to ensure that $u' > 0$. Condition (13) follows naturally given the previous assumptions on $c(\cdot)$ in section 2.

To infer condition (14), we define $G(z) \equiv (c''(z))^2 - c'(z)c'''(z)$. Given the previous assumptions on $c(\cdot)$ in section 2, we see that $G(0) > 0$. Differentiating G, we obtain $G' = c''c''' - c'c''''$ which is non-negative (i.e. G is non-decreasing) if $c''' > 0$ and $c'''' \leq 0$. This in turn ensures that $G(z) > 0 \quad \forall z \geq 0$ if (14) holds.

Thus, either (13) or (14) is sufficient to ensure that $u' > 0$. □

We proceed assuming that either condition (13) or (14) holds. While the assumption of $\Theta' > 0$, i.e. monotone hazard is analogous to assumption A10 in [6, chapter 7], the further assumptions on the cost function $c(\cdot)$ are analogous to assumption A8 in [6, chapter 7].

Given the assumptions required for implementability and sufficiency of the contract, we can show that the faking level given by $x - u(x)$ decreases with the agent's type x. This is demonstrated via the following corollary.

Corollary. *The faking level $x - u(x)$ reduces with agent type x. The lowest type x_L fakes the most, and the highest type x_H reports revenue truthfully, i.e., $u(x_H) = x_H$.*

Proof. Let $z \equiv x - u(x)$, which denotes the level of faking for freelancer of type x. Thus (10) reduces to $c'(z)/c''(z) = 1/[\Theta(x)(1-\delta)]$, where $\Theta(x)$ is the hazard function. We can differentiate both sides with respect to x to get:

$$\frac{[(c'')^2 - c'c''']}{(c'')^2}\frac{dz}{dx} = -\frac{1}{(1-\delta)}\frac{\Theta'}{\Theta^2}$$

Given the results of the lemma, i.e. $\Theta' > 0$ and $(c'')^2 - c'c''' > 0$, it is evident that $dz/dx < 0$, i.e. the faking level reduces with type.

Also, substituting $x = x_H$ in (10), we see that $c'(x_H - u(x_H))/c''(x_H - u(x_H)) = 0$ since $F(x_H) = 1$, i.e. $x_H = u(x_H)$.

□

Thus we see that the efficient contract tolerates more faking by freelancers of lower types, and incentivizes higher types to be more truthful.

2.2 Revenue sharing contract without variable payment

In a setting without the existence of a variable payment, the principal's payoff assumes the form:

$$\widetilde{\Pi}(\gamma, u(x)) = \alpha u(x) + \gamma\delta c(x - u(x)) - h(\gamma) \tag{15}$$

and the agent's payoff becomes:

$$\widetilde{Y}(\gamma, u(x)) = x - \alpha u(x) - \gamma c(x - u(x)) \tag{16}$$

Comparing the above payoff function with one featuring a variable payment as presented in equation (1) leads to the following relation between the two:

$$\Pi = \widetilde{\Pi} - v(x) \tag{17}$$

$$\Rightarrow \mathbb{E}(\Pi) = \mathbb{E}(\widetilde{\Pi}) - \mathbb{E}(v(x)) \tag{18}$$

This implies that if $\mathbb{E}(v(x)) < 0$, the expected payoff of the principal is higher in the presence of variable payments. We present a sufficient condition under which the expected payoff of the principal with variable payment exceeds that under no variable payment in the following proposition.

Proposition 2. *Under the following sufficient condition, the principal's expected payoff with variable payment exceeds that under no variable payment.*

$$\alpha \leq \left(\frac{1-\gamma}{\mathbb{E}(x)}\right) x_L \tag{19}$$

Proof.

$$\begin{aligned} v(x) &= \alpha u(x) - x + \gamma c(x - u(x)) + \int_{x_L}^{x} [1 - \gamma c'(t - u(t))]\, dt \\ &= \alpha u(x) - x_L + \gamma \left[c(x - u(x)) - \int_{x_L}^{x} c'(t - u(t)) dt\right] \end{aligned} \tag{20}$$

For the convex function $c(\cdot)$, the subgradient inequality, for any $y \neq z$ is:

$$\begin{aligned} c(y) &\geq c(z) + c'(z)(y - z) \\ \text{Let} \quad & y \equiv 0; \quad z \equiv x - u(x) \\ c(0) &\geq c(x - (u(x)) - c'(x - u(x))(x - u(x)) \\ \Rightarrow c(x - u(x)) &\leq c'(x - u(x))(x - u(x)) \end{aligned} \tag{21}$$

Substituting (21) in (20):

$$v(x) \;\; \leq \;\; \alpha u(x) - x_L + \gamma \left[(x - u(x))c'(x - u(x)) - \int_{x_L}^{x} c'(t - u(t))dt \right] \qquad (22)$$

Note that the integral above is for the variable t whose lower limit is x_L and upper limit is x. From the first order condition (10), we know that lower types fake more than higher types. Further, $c(\cdot)$ is convex, with $c'(\cdot) > 0$. Thus:

$$\begin{aligned} & x_L \leq t < x \leq x_H \\ & \Rightarrow c'(x_L - u(x_L)) \geq c'(t - u(t)) > c'(x - u(x)) \geq c'(x_H - u(x_H)) = 0 \end{aligned} \qquad (23)$$

Substituting (23) in (22):

$$v(x) \leq \alpha u(x) - x_L + \gamma \left[(x - u(x))c'(x - u(x)) - c'(x - u(x)) \int_{x_L}^{x} dt \right]$$

Note that in the above integral we have replaced the larger quantity $c'(t - u(t))$ with the smaller $c'(x - u(x))$, thus preserving the inequality. The term is also independent of t and thus can be put outside the integral, leading to:

$$\begin{aligned} v(x) &\leq \alpha u(x) - x_L + \gamma \left[(x - u(x))c'(x - u(x)) - c'(x - u(x)) \int_{x_L}^{x} dt \right] \\ &= \alpha u(x) - x_L + \gamma \left[(x - u(x)) - (x - x_L) \right] c'(x - u(x)) \\ &= \alpha u(x) - x_L - \gamma (u(x) - x_L) c'(x - u(x)) \qquad (24) \\ &= \alpha u(x) - x_L - \gamma u(x) c'(u(x) - x) + \gamma x_L c'(x - u(x)) \end{aligned}$$

since $c'(\cdot) < 1$ by assumption and $u(x) \leq x$ in the optimal contract:

$$v(x) \leq \alpha x - (1 - \gamma) x_L \qquad (25)$$

Thus, pointwise, $v(x) \leq 0$ provided $\alpha x - (1-\gamma)x_L \leq 0$. Taking expectations, $\mathbb{E}(v(x)) \leq 0$ if $\alpha \mathbb{E}(x) - (1 - \gamma)x_L \leq 0$, i.e., $\alpha \leq (1 - \gamma)x_L / \mathbb{E}(x)$. □

In the absence of detected fraud, the total payment the principal makes to the agent is given by $x - \alpha u(x) + v(x)$. The total payment made is always non-negative even though $v(x)$ may be negative. A negative value of $v(x)$ indicates that the principal can extract a higher surplus in equilibrium from some types of the agent as compared to a revenue-sharing contract without the bonus. Thus, the variable component $v(x)$ is an additional lever, for the principal to extract more value from the agent, compared to a fixed fraction revenue sharing contract.

2.3 Numerical illustration

A brief numerical illustration follows. For clarity of exposition, we assume the following functional forms:

$$h(\gamma) = 10^6\gamma^3 \tag{26}$$

$$c(x - u(x)) = \frac{(x - u(x))^2}{225} \tag{27}$$

Further, we assume that x is uniformly distributed in $[100, 101]$:

$$f(x) = 1 \tag{28}$$

$$F(x) = x - 100 \tag{29}$$

Note that as 101 is the maximum possible value of $x - u(x)$, (27) always satisfies (7). Substituting (27)–(29) in (10), we get,

$$x - u(x) = \frac{101 - x}{1 - \delta} \tag{30}$$

$$u(x) = \frac{(2 - \delta)x - 101}{1 - \delta} \tag{31}$$

The principal's audit effort is the solution of

$$3 \times 10^6\gamma^2 = \int_{100}^{101} \frac{\delta}{225}\left(\frac{101 - x}{1 - \delta}\right)^2 \times 1dx = \frac{\delta}{675(1 - \delta)^2} \tag{32}$$

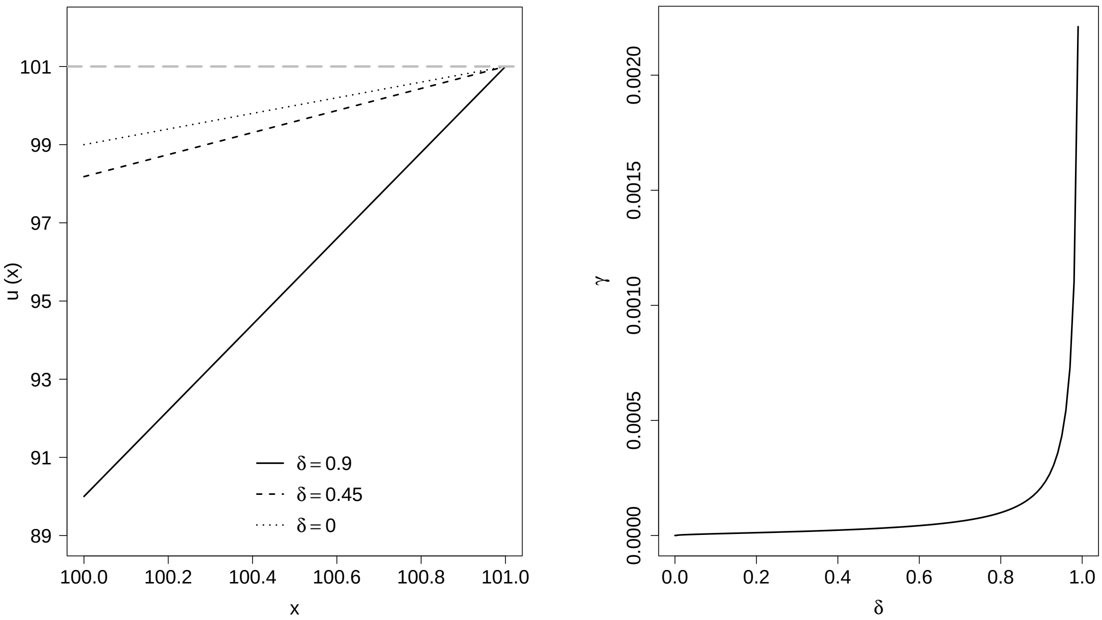

Figure 1: Illustration of revenue reporting function $u(x)$ as a function of type x for different values of restitution factor δ (left); and the principal's audit effort γ as a function of δ (right).

which is obtained by substituting (26), (28) and (30) in (8). This yields:

$$\gamma = \frac{\sqrt{\delta}}{45000(1-\delta)} \tag{33}$$

Figure 1 illustrates reported revenue $u(x)$ and audit effort γ for different parameter values. The left figure illustrates how misreporting increases (i.e. $u(x)$ decreases) as δ increases, while the right plot illustrates the equilibrium audit effort γ as a function of δ. As the left plot shows, especially for lower freelancer types, $u(x) < x_L = 100$, which implies that the reported revenue is strictly below the lowest possible value which the platform can expect. Yet, for the sake of efficient screening, the platform tolerates this obvious evidence of faking. We note that this result, though counter-intuitive, has been observed in prior related studies as well [3, 10].

Further, based on the functional specification for faking cost and type distribution for this illustration, we calculate the variable payment, and the payoffs of the freelancer and the platform below:

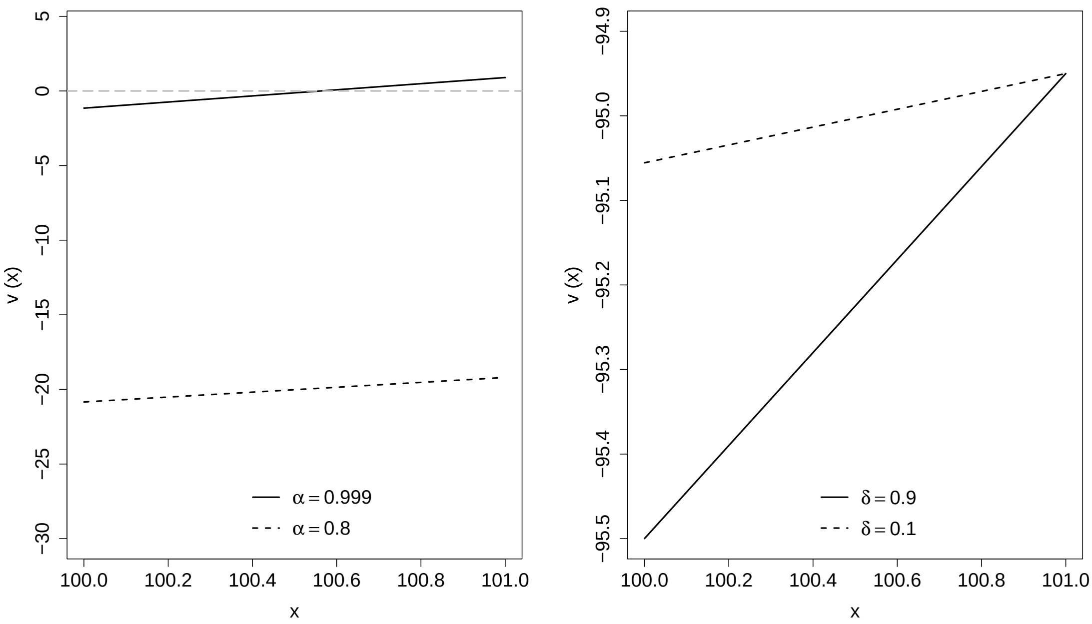

Figure 2: The variable payment schedule for different values of α (left) and δ (right). For the left plot, $\delta = 0.05$; for the right plot, $\alpha = 0.05$.

$$
\begin{aligned}
v(x) &= \frac{\sqrt{\delta}\,(x^2 - 202x + 10200)}{10125000(\delta-1)^2} + \frac{\alpha((2-\delta)x - 101)}{1-\delta} \\
&\quad + \frac{\sqrt{\delta}\left(x - \frac{(2-\delta)x-101}{1-\delta}\right)^2}{10125000(1-\delta)} - 100 \qquad (34) \\
Y(x) &= \frac{\sqrt{\delta}\,(x^2 - 202x + 10200)}{10125000(\delta-1)^2} + x - 100 \qquad (35) \\
\Pi(x) &= -\frac{\delta^{3/2}}{91125000(1-\delta)^3} - \frac{\sqrt{\delta}\,(x^2 - 202x + 10200)}{10125000(\delta-1)^2} \\
&\quad + \frac{\delta^{3/2}\left(x - \frac{(2-\delta)x-101}{1-\delta}\right)^2}{10125000(1-\delta)} \\
&\quad - \frac{\sqrt{\delta}\left(x - \frac{(2-\delta)x-101}{1-\delta}\right)^2}{10125000(1-\delta)} + 100 \qquad (36)
\end{aligned}
$$

Figure 2 illustrates the variable payment as a function of α (left) and δ (right). The central insight of proposition 2 can be observed in the left plot, where we observe that for some values of x, $v(x)$ is negative. Finally, we also present the plots for the payoffs of the freelancer and the platform in figure 3. We observe here that for various combinations of

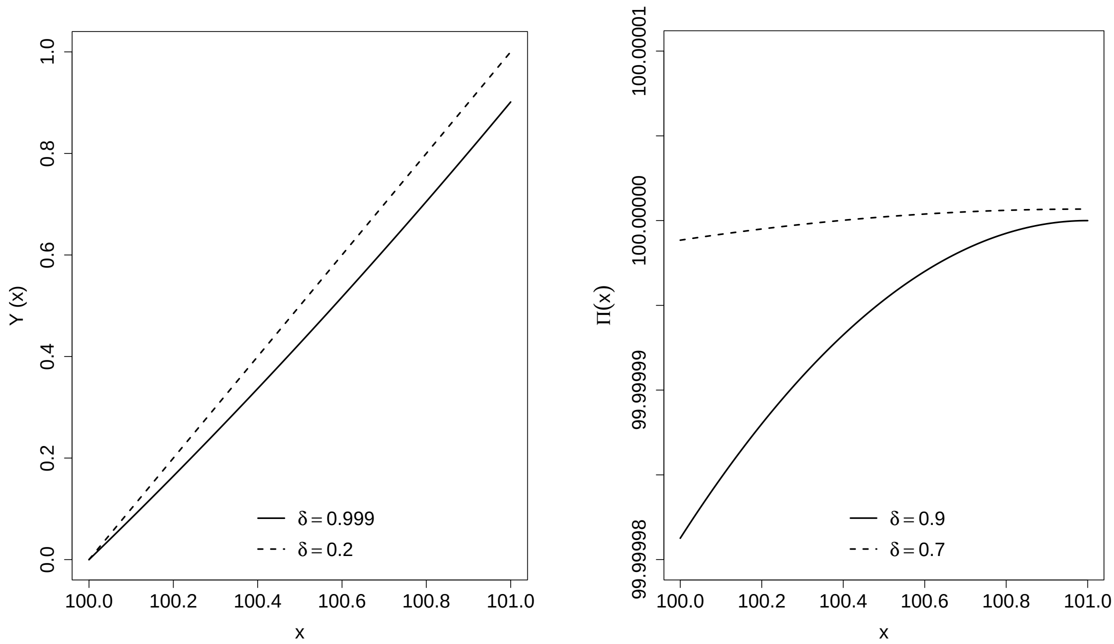

Figure 3: The payoff functions of the freelancer, $Y(x)$ (left) and the platform, $\Pi(x)$ (right) as functions of the exogenous restitution parameter δ. Different values of δ are chosen for ease of illustration.

the exogenous parameters δ and α, the principal's payoff function Π can be very different. Yet for any given (α, δ) combination, Π does not change much with the agent type x. This relatively low sensitivity of the principal's payoff function to the agent type is due to the functional forms chosen for this illustration.

3 Sensitivity Analysis

We now analyze the sensitivity of two endogenous outcomes—the reported revenue $u(x)$ and the platform's audit effort γ—to the exogenous parameters α, δ.

Proposition 3. *The agent's reporting function $u(x)$ satisfies:*

$$\frac{du}{d\alpha} = 0 \tag{37}$$

$$\frac{du}{d\delta} = -\left(\frac{1-F}{f}\right)\left(\frac{1}{1-\delta}\right)^2\left(\frac{(c'')^2}{(c'')^2 - c'c'''}\right) < 0 \quad \forall\, x < x_H \tag{38}$$

Proof. Differentiating both sides of (10) with respect to α yields the result (37). Differentiating both sides of (10) with respect to δ and simplifying, yields (38). Looking at its right hand side, it is obvious that the terms $(1-F), f, (1-\delta)^2$ and $(c'')^2$ are positive. However, our assumptions on $c(\cdot)$ in section 2 and further assumptions outlined in the lemma also ensure that $(c'')^2 - c'c''' > 0$, ensuring that $du/d\delta < 0$. □

Proposition 4. *The principal's audit effort γ satisfies:*

$$\frac{d\gamma}{d\alpha} = 0 \tag{39}$$

$$\frac{d\gamma}{d\delta} = \frac{1}{h''(\gamma)}\left(\bar{c} + \delta\frac{d\bar{c}}{d\delta}\right) > 0 \tag{40}$$

where $\bar{c} \equiv \int_{x_L}^{x_H} c(x-u(x))f(x)dx$ is the expected penalty of misreporting across all types in $[x_L, x_H]$.

Proof. Differentiating both sides of (8) with respect to α yields the result (39). Differentiating both sides of (8) with respect to δ and simplifying yields (40). Now, $h'' > 0$ by assumption. Also, (38) establishes that for any $x < x_H$, $u(x)$ decreases with δ, and hence the level of misreporting $x - u(x)$ increases. Thus, the penalty $c(x-u(x))$ increases point-wise in $[x_L, x_H)$, and therefore the expected penalty $\bar{c}$ also increases, i.e. $d\bar{c}/d\delta > 0$. Thus, the entire right hand side is positive. □

Propositions 3 and 4 provide valuable insights. First, we demonstrate that the revenue share fraction α affects neither the reported revenue of the agent, nor the audit effort of the principal, as indicated by (37) and (39). For any given level of misreporting $x - u(x)$, the parameter δ represents the principal's (platform) ability to extract restitution. This in turn, incentivizes it to expend more audit effort (probability) γ. However, given the agent's payoff function, this perversely encourages more under-reporting by the agent.

In reality, the restitution factor δ can be seen either as an industry practice or a legislation by policy makers, presumably to benefit the principal. Indeed, a restitution clause seems to be ideal to deter cheating by the agent (freelancer). However, we show that this is not the case—it is better to let the agents suffer reputational damages without passing on any part to the principal.

4 Conclusion

Our model illustrates the incentives of platform exploitation. Auditing fraudulent freelancers is costly since it requires expending resources for inspecting potentially millions of freelancers. The freelancers themselves exploit the information asymmetry and knowledge of costly audits to misreport earnings strategically. Platform exploitation is inevitable in our optimal contract, explaining its widespread prevalence in the sharing economy.

Our model paves the way for some interesting extensions. First, we restrict ourselves to the case where the freelancer is unable to develop long-term relationships with customers—a reasonable assumption for services like carpooling (e.g. Uber, Lyft) or short term property rentals (e.g. AirBnB). However, other settings like medical care ([16]'s seminal study uses data from an unnamed company providing such services), long-term rentals (e.g. the Indian portal Nestaway) and household services (e.g. the Indian portal Urban Company), could lead to very different incentive structures for both platforms and freelances. Second, the contract between platform and freelancer could incorporate moral hazard, where the platform also incentivizes unobservable effort by the freelancer. Third, it is worthwhile introducing competition among multiple platforms and/or freelancers in the model.

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