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RATINGS & RECIPROCITY

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RATINGS & RECIPROCITY

Abstract

We explore how firms use prices to impact their ratings. To do so, we follow extensive evidence that reciprocity motivates ratings and incorporate reciprocity into a model of ratings: consumers rate a seller if they get a sufficient value-for-money. We show firms harvest ratings: they offer lower prices in early periods to trigger consumers' reciprocity and improve ratings and future profits. We show this mechanism implies that (i) reciprocity-based ratings cause rating inflation; (ii) facilitating ratings (through reminders, pay-to-rate...) leads to more- but less-informative ratings. Consumers benefit from lower prices despite less-informative ratings, and prefer more-informative ratings than average sellers.

JEL Classification: D21, D83, D90, L10

Keywords: Reciprocity, Ratings, Ratings inflation, Seller reputation

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Ratings & Reciprocity

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March 10, 2023

Abstract

Evidence suggests online ratings and reviews are motivated by reciprocity. We incorporate a standard model of reciprocity into a model of ratings to capture that consumers are only willing to make the effort to rate a seller if this seller provides a *sufficient* value-for-money. Using this model, we explore how firms use prices to impact their own ratings. We show that firms harvest ratings: they offer lower prices in early periods to trigger consumers' reciprocal behaviour and obtain a good rating and larger profits in the future. Because also low-quality firms harvest ratings, reciprocity makes ratings less-informative about quality. Based on this mechanism, (i) we argue that reciprocity-based ratings cause rating inflation; (ii) we show that a marketplace that facilitates ratings (e.g. through reminders, one-click ratings etc.) may get more ratings, but also less-informative ratings; (iii) a marketplace that screens the quality of sellers makes ratings less-informative if the screening is insufficient. We show that even as ratings become less-informative, consumers can benefit from lower prices. Nonetheless consumers prefer more-informative ratings than average sellers. We apply these results to characterise when a two-sided platform wants to facilitate ratings, and thereby undermines the informativeness of ratings and harms consumers.

JEL: D21, D83, D90, L10

Keywords: Reciprocity, Ratings and Reviews, Digital Economy, Reputation

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1 Introduction

Ratings feature prominently in the decisions we make each day. We often rely on the experience of others, through ratings and reviews, to make decisions. Examples include choosing a holiday resort, buying a car, or where to have lunch. But how far can we trust these ratings to inform us about the quality of a product?

Despite having an influential role on the way consumers make purchase decisions, evidence suggests that ratings can be a poor signal of objective product quality (De Langhe et al., 2016; Siering et al., 2018). Empirical work highlights that prices influence ratings. For example, Li and Hitt (2010) show that a 1% increase in price lowers ratings by 0.7 on a 1-10 point scale, so the effect of price on ratings can be quite sizeable.[1] While this suggests that prices affect ratings, other evidence shows that firms with better ratings have the ability to set higher prices (Luca & Reshef, 2021). Combined, this evidence suggests a dual role between prices and ratings. Firms use lower prices to obtain good ratings, as this allows them to set higher prices in the future.

The body of theoretical literature on reputation tends to assume that reputation is solely a consequence of quality. In doing so, these papers focus on only one direction of effects: how ratings can influence future prices. In this paper, we contribute to the theoretical literature by considering the dual role of prices in ratings. We address the question: "are value-for-money based ratings informative of product quality?"

To develop a framework where prices influence ratings, we build on the well-established concept of reciprocity (Bolton & Ockenfels, 2000; Dufwenberg & Kirchsteiger, 2004; Rabin, 1993). Evidence on reciprocity suggests that firms may choose to lower prices or provide rebates to offer a higher value-for-money to consumers. These consumers interpret a sufficiently high value-for-money as a kindness, which they reciprocate with a good rating (Fradkin et al., 2021; Halliday & Lafky, 2019; Li & Hitt, 2010). Reciprocity allows us to capture that consumers rate based on observed quality and price, and reward 'good' deals with a good rating. Given the true quality and price, the consumer is willing to make the effort to rate if a seller made a *sufficiently* kind offer, measured in terms of value-for-money. If the consumer receives a sufficiently high value-for-money, then they are willing to reciprocate the firm's kindness with an act of kindness of their own in the form of a good rating. Thus, we endogenize the rating decision of consumers, and enable firms to use prices to influence ratings.

[1] They look at overall product ratings on CNET.com and Dpreview.com. The effect has a similar magnitude when consumers are asked to rate value-for-money explicitly.

Formally, we study a two period model with asymmetric information. Two actors participate in each period—a long lived monopolistic firm and a short lived consumer. The firm is endowed with a product of high or low quality. The firm knows the quality of its product, and sets prices in each period to maximise lifetime profits. Initially, consumers only know the distribution of quality. Each consumer only participates in a single period. At the start of each period, consumers observe the historical ratings of the firm and its price in the current period. Consumers only learn of the true quality of the product after consumption, and may then choose to leave a rating. Thus, consumers are uncertain about quality at the beginning of each period; but they may use ratings to transmit some information about quality to future consumers.

This model is representative of markets such as Amazon and Taobao, where ratings play the important role of developing trust between anonymous users. In these markets, new consumers are mostly unaware of the true quality of sellers they are transacting with. They rely on information left by prior consumers—through ratings—to form beliefs over the quality of a product. Further, these websites only list historical ratings and current prices.[2]

In line with evidence that high-quality firms are more likely to get good ratings (Ananthakrishnan et al., 2019; Li et al., 2020), we focus on equilibria where high-quality firms set sufficiently low prices to obtain a good rating.

Our key mechanism is that low-quality firms face the following trade-off. First, in period 1 they can set a price which is sufficiently low to trigger reciprocity. By doing so, the low-quality firm receives a good rating and earns larger profit in period 2. We call this strategy *'ratings harvesting'*. Second, in period 1 the low-quality firm could charge the same price as the high-quality firm to make consumers believe this seller could be of a high quality. Because both firms charge the same price in period 1, we call this strategy *'price mimicking'*.

This trade-off of low-quality firms influences how well consumers can infer quality from ratings. If low-quality firms harvest ratings, both types of firms get a good rating, and future consumers cannot use ratings to distinguish firms. But if low-quality firms mimic prices, only high-quality firms offer a sufficiently high value-for-money to obtain a good rating, allowing future consumers to distinguish firms.

In equilibrium, if consumers have a weak tendency to reciprocate, only high-quality firms obtain a rating and ratings perfectly signal quality. But if consumers are more inclined to reciprocate value-for-money, low-quality firms play a mixed-strategy, and do both price

[2]While some services may exist to attempt to track historical prices, their validity cannot be ascertained and these services are unable to reflect the transaction price associated with each rating.

mimicking and ratings harvesting with positive probability. Intuitively, low-quality firms harvest ratings to get a good rating and free-ride on the reputation of high-quality firms. But this undermines the value of a good rating until, in equilibrium, low-quality firms are indifferent between ratings harvesting and price mimicking. This mixed-strategy equilibrium endogenously determines how well ratings signal quality: low-quality firms obtain a good ratings if and only if they harvest ratings. This is why the probability that low-quality firms mimic prices in equilibrium also measures how well ratings signal quality. We leverage our key trade-off to understand how changes in the ratings environment impact the informativeness of ratings.

The dynamic pricing in our mixed-strategy equilibrium closely resembles evidence on rating harvesting: in online marketplaces, firms build reputation in early periods by obtaining good ratings. Subsequently, they increase prices (Cabral & Hortaçsu, 2010; Cabral & Li, 2015; Li et al., 2020).

Our main mechanism implies that reciprocity makes ratings less-informative and causes rating inflation.[3] Intuitively, when consumers have a stronger sense of reciprocity, firms need only leave a smaller surplus to trigger consumer's reciprocal behavior. This means that firms can set a higher price and still receive a good rating. Therefore, low-quality firms harvest ratings more often and receive better ratings. But if low-quality firms get better ratings, ratings become less-informative about quality.

Even though ratings harvesting makes ratings less-informative, consumers may still benefit: low-quality firms who harvest ratings lower prices and provide some surplus to consumers. We call this surplus 'reciprocity rent'. Since consumers only receive this surplus when firms harvest ratings, they benefit despite less-informative ratings. This has two key implications: (i) Consumers do not prefer fully-informative ratings. If low-quality firms do not harvest ratings, ratings are perfectly-informative, but consumers do not receive any reciprocity rent. (ii) Counter to the conventional wisdom that consumers mainly benefit from ratings via the information they transmit, we show that consumers may benefit from lower prices that firms charge to induce better ratings.

Next, we explore how different features of a marketplace influence ratings, namely (i) how easy it is to rate and (ii) the extent of quality controls.

Many platforms try to encourage and facilitate ratings by lowering the effort it takes for

[3]Rating inflation here refers to the observation that ratings scores are improving over time, and most of the improvements cannot be attributed to product quality. Thus, leading to ratings becoming a less effective signal of quality. This observation is made in Filippas et al. (2022), suggesting that other attributes such as the cost of leaving ratings, kindness to seller and other forms of retaliation contributes to rating inflation.

consumers to leave a rating. For example, Amazon transitioned to a one-click rating system, arguing that—in the spirit of the law of large numbers—more ratings "more accurately [...] reflect the experience of all purchasers".[4,5] We show that this logic ignores how a lower effort to rate impact how sellers harvest ratings. Making it easier to rate means that firms need only transfer a smaller reciprocity rent to consumers to encourage a good rating. Thus, low-quality firms can harvest ratings with higher prices and will do so more often in equilibrium. Even though this leads to more ratings in equilibrium, ratings are also less-informative. Evidence suggests these effects can be quite large: Cabral and Li (2015) pay consumers to leave any rating to lower their opportunity cost to rate; they find that giving consumers 1$ to leave any rating leads to 22% less negative ratings.[6] More generally, together with evidence that platforms facilitate ratings over time, this result suggests platforms engage in a race towards uninformative ratings and reinforce rating inflation.

This result also suggests that recent policy proposals to improve rating environments may not go far enough. Crawford et al. (2021) propose that sellers should not be able to pay raters conditional on the content of their ratings or reviews. We show that even unconditional payments for ratings—even when not discriminating between worse or better ratings—leads to less-informative ratings.

We show that easier ratings affect buyer- and seller-surplus differently. Sellers have polarized views on ratings: High-quality firms unambiguously prefer a higher effort to rate, because this prevents other firms from free-riding on their reputation. But a higher effort to rate reduces reciprocity rents and average sellers prefer easier ratings. Consumers, however, prefer an intermediate effort level that leads to somewhat-informative ratings. Thus, consumers prefer more-informative ratings than the average seller, but less-informative ratings than high-quality firms.

These results suggest that a platform can facilitate or discourage ratings to shift surplus between sellers and buyers. Using this insight, we show when a two-sided platform may facilitate ratings to encourage more ratings, but less-informative ratings.

Marketplaces do not just facilitate ratings, but also employ quality controls to weed out low-quality firms. For example, Amazon suspends sellers who do not meet a minimum standard.[7] We show that improving the aggregate quality in the market can discourage

[4]Quote from article Rey (2020) on vox.com.

[5]Prior to 2019, Amazon had required raters to leave a 20-word review along with their rating. Documented by Amazon reviews and forums (Amazon Customer, 2012; crebel, 2017).

[6]They do their field experiment in a field experiment on eBay. Effectively, 1$ discount amounts to a price reduction of 25%.

[7]See information disseminated to sellers by Amazon (Rushdie, 2018) and a Bloomberg news article (Soper,

ratings harvesting, leading to more-informative ratings and less rating inflation. But when aggregate quality is low, quality improvements can also foster rating inflation instead.

Finally, we study a range of extensions and robustness checks. We show that competition between sellers encourages ratings harvesting and leads to more rating inflation. Additionally, our results are robust when consumers can leave negative ratings. In this extension, we show that reciprocity can explain why we observe extreme (very positive or negative) ratings in practice. In an extension beyond two periods, we capture the evidence that firms harvest ratings, but that lower-quality firms are less likely to maintain good ratings (Cabral & Hortaçsu, 2010; Jin & Kato, 2006). We also show that our results persist when we introduce a continuum of firms.

We introduce the basic model in Section 2, and discuss the equilibrium in Section 3. Section 4 shows how various features in the rating system influence how well ratings reflect quality. We then discuss implications on surplus in Section 5. We present extension and robustness checks in Section 6. Section 7 connects our results to the literature, and Section 8 concludes.

2 Basic Model

We set up a two-period model of incomplete information with a long lived monopoly firm and a unit mass of buyers in each period.

Firms. The firm can be of a high or low quality. A firm of type $j \in \{L, H\}$ has quality q^j, where $q^L < q^H$. The probability that the firm is of type q^H or q^L is common knowledge and given by $\gamma \in (0, 1)$ and $(1 - \gamma)$, respectively. The realized quality is private information to the firm and is constant between periods. In each period, the firm sets the price of its product to maximise its lifetime profit, $\sum_{t=1}^{2} p_t^j \cdot d_t^j$, where p_t^j is the price of firm j in period t, and $d_t^j \in \{0, 1\}$ is the demand of firm j in period t. We assume that the cost of production is zero regardless of quality.[8] After selling in period 1, sellers may receive a rating R_1 from consumers. If they do, this rating is made common knowledge to both the firm and consumers in subsequent periods.

2019).

[8]We only require that low-quality firms face a smaller marginal cost than high-quality firms. Without loss of substance, it simplifies the analysis to assume that both firms face zero cost of production. This is similar to allowing for costless signals in a cheaptalk game (see Kreps and Sobel (1994) and Crawford and Sobel (1982)). Additionally, our model features a concept of endogenous cost such as that in Martin and Shelegia (2021). In our setting, by harvesting ratings, low-quality firms reduce the benefit of ratings harvesting.

Consumers. Consumers have homogeneous valuations, participate in only one of the two periods, with a new unit mass of consumers arriving in each period. We normalize the value of their outside option to zero. When choosing to consume a product in period t, consumers observe the price on offer and past ratings, R_{t-1}. They do not observe the firm's quality or past prices. Consumers may choose to buy or not to buy. If they choose not to buy, they exit the market. If they consume, they observe the firm's true quality and decide on leaving a rating. For simplicity, in the main model, we focus on a binary rating system where consumers can choose between leaving a rating or not. More precisely, ratings take the form $R_t \in \{0, 1\}$. The informational content of a rating will be determined in equilibrium, but we say that a rating is good if $R_t = 1$, and when $R_t = 0$, consumers choose not to provide any rating. We focus on positive ratings to simplify exposition and we show below that our main results are qualitatively robust when consumers are additionally able to leave bad ratings.[9] Without loss of generality, we say $R_0 = 0$, i.e. firms have no previous ratings.[10]

We distinguish between consumption utility and rating utility. This serves two purposes. First, we are able to capture the phenomenon that consumers do not factor the intention to rate into their purchase decision.[11] Second, this simplifies presentation of results. The consumption utility for consuming a product from firm j in period $t \in \{1, 2\}$ is given by $u_t = q^j - p_t^j$, where p_t^j represents the price that the firm sets in period t.

The rating utility captures intrinsic reciprocity models as in Dufwenberg and Kirchsteiger (2004) and Rabin (1993).[12] For consumers in period t it is given by $v_t = [\kappa q^j - p_t^j]\Delta - e$ if $R_t = 1$ and $v_t = 0$ if $R_t = 0$. $\kappa \in [0, 1]$ represents the proportion of surplus which consumers think is equitable for firms to receive; $\Delta > 0$ represents the warm glow a consumer enjoys from the kindness of leaving a rating to the firm; and $e \geq 0$ reflects the opportunity cost of providing a rating.

The first term $[\kappa q^j - p_t^j]$ captures the consumer's perception of the firm's kindness. Consumers perceive a price equal κq^j as fair. Thus, they perceive any price below κq^j as a kindness, and $[\kappa q^j - p_t^j]$ is positive. Otherwise, if $[\kappa q^j - p_t^j]$ is weakly negative, firms keep more surplus than what consumers deem as equitable, and consumers perceive firms as unkind.

The second term Δ describes the consumers' sense of reciprocity and captures the warm

[9]We start with an environment where negative ratings do not exist to simplify exposition of results. We discuss how our results extend to a setting with negative ratings that punish bad deals in Section 6.

[10]This captures cases where the firm is new in the market. More generally, our model captures cases where two firms of different quality have the same rating at the beginning of period 1.

[11]This is highlighted by Cabral and Li (2015), who show that incentivizing consumers to rate does not change the number of bids or bid levels on eBay, indicating that consumers do not consider the rating incentives when making a purchase.

[12]Derivation can be found in the Web Appendix B.3.

glow that consumers receive from being kind to a firm by leaving a good rating. Finally, the consumer faces some costs when leaving a rating e, such as time, effort, attention etc. Below, we consider that e may depend on the design of a ratings systems, for example, one-click ratings, constant reminders, and purchase verification.

Timing of game. To summarize the timing of the game,

$t = 1$

- Firm draws quality, q^j.
- Firm sets price, p_1.
- Consumers observe price and form expectations over consumption utility, u_1.
- Consumers make purchase decision, if $u_1 \geq 0$.
- Consumers that purchase observe true quality.
- Consumers evaluate rating utility, and rate if $v_1 \geq 0$.
- Period 1 consumers exit the market.

$t = 2$

- Period 2 consumers arrive.
- Firm observes historical rating, R_1, and sets new price, p_2.
- Consumers observe past ratings and current price, forming expected quality.
- Consumers make purchase decision.

In the main model, we make some simplifying assumptions. We discuss in Section 6 how results are robust to various extensions, namely a game with more than 2 periods, a continuum of quality types of the firm, and a rating system with positive, and negative ratings.[13]

This model is representative of markets such as Amazon, Taobao, eBay, AirBnB[14] and Google reviews. These platforms help to facilitate matches between consumers and firms. Consumers rely on ratings to form or update their expectations of product quality. Firms

[13] Lewis and Zervas (2019) show that only the relative difference in stars affects the pricing decision of firms. This suggests that it is more important to consider the effect of a relative difference in ratings, which we already do with our simple binary-rating framework. Other papers find that negative ratings have a statistically insignificant impact on prices (Bajari & Hortaçsu, 2003; Cabral & Hortaçsu, 2010; Livingston, 2005; Resnick et al., 2006). Hence, we believe that this simplification is well justified. Although, as we show in our extension, allowing for more flexibility in the ratings scale does not qualitatively change our result.

[14] Although we do not explicitly capture the mutual nature of AirBnB's rating system, ratings on AirBnB are only revealed after both host and guest have provided a rating. This removes the threat of retaliation rating-for-rating in response to a negative rating, which is why AirBnB and other similar mutual rating system resemble our one-directional rating system.

use ratings to differentiate themselves from lower quality firms, allowing them to build trust and gain patronage.

3 Equilibrium

We look for a perfect Bayesian equilibrium. We apply two additional restrictions as equilibrium selection assumptions.[15]

Restriction 1. *We focus on the equilibria where high-quality firms obtain a rating of $R_1 = 1$ with probability 1.*

The restriction implies that consumers who observe a rating expect weakly higher quality of the product. We focus on such equilibria in line with evidence that high-quality firms are more likely to receive good ratings (Ananthakrishnan et al., 2019; Li et al., 2020).[16] Importantly, Restriction 1 allows us to focus on the strategic decisions of low-quality firms.

We make a second selection assumption to limit off-the-path beliefs.

Restriction 2. *For all prices in period t such that low-quality firms obtain no rating, the expected quality in period t is independent of prices.*[17]

Restriction 2 implies that in a given period t, consumers have the same beliefs about quality for any price that induces the same average consumer rating. The restriction captures that firms can mimic each others' prices, making prices a poor signal of quality. More precisely, because all firms have zero marginal cost, low-quality firms can always deviate to any price set by a high-quality firm. This makes it difficult for high-quality firms to use price signals to differentiate themselves from low-quality firms.

Together, these restrictions give ratings the best shot at being an informative signal for product quality. Restriction 1 focuses on equilibria where high-type firms always receive a good rating, and Restriction 2 ensures that the information signal that future consumers receive comes from ratings alone.

The following proposition characterizes equilibria in this game.

[15] These restrictions are similar in spirit to those used in Rhodes and Wilson (2018), who study how advertisement can signal quality.

[16] Formally, equilibria where high-quality firms prefer to get a rating with probability 1 exist if κ is sufficiently large. Intuitively, when κ is large, the high-quality firm can charge a high price and still receive a good rating. This reduces their incentive to deviate to prices even closer to or at q^H, at which they receive no rating.

[17] Alternatively, we could use the D1 refinement, but we choose to use Restriction 2 instead, as it is weaker restriction and more intuitive (Cho & Sobel, 1990).

Proposition 1. *All perfect Bayesian equilibria satisfy the following.*

1. *In period 1, high-quality firms charge* $\overline{p} \equiv \frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)}$ *with probability 1 and receive a good rating.*

2. *In period 1, low-quality firms randomize their price.*

   a. *They charge* $\overline{p}$ *with probability* δ^* *and obtain no rating.*

   b. *They charge* $\underline{p} \equiv \kappa q^L - \frac{e}{\Delta}$ $(< \overline{p})$ *with probability* $1 - \delta^*$ *and obtain a good rating.*

   c. $\delta^* \in (\frac{1}{2}, 1)$ *if and only if*

$$(1-\gamma)(q^H - q^L) - (1-\kappa)q^L > \frac{e}{\Delta}, \tag{1}$$

   and $\delta^* = 1$ *otherwise.*

3. *In period 2, prices equal expected quality conditional on ratings.*
$$E[q_2|R_1] = \begin{cases} \frac{\gamma q^H + (1-\delta^*)(1-\gamma)q^L}{\gamma + (1-\delta^*)(1-\gamma)} & \text{if } R_1 = 1 \\ q^L & \text{if } R_1 = 0 \end{cases}.$$

The equilibrium is unique up to off-equilibrium-path beliefs and exists if $\kappa q^H - \frac{e}{\Delta} \geq \frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)}$.[18]

Firms charge one of two prices in equilibrium. High-quality firms always set $\overline{p}$ to extract all expected surplus (conditional on observing $\overline{p}$).[19] If consumers could distinguish high- and low-quality firms, this price would be equal to q^H. But because in period 1 consumers cannot distinguish firms, low quality firms can mimic the high-quality firm and charge $\overline{p}$. This, in equilibrium, can lower the conditionally expected surplus below q^H. The low price $\underline{p}$ is just low enough so that consumers perceive low-quality firms as sufficiently kind to give them a good rating, i.e. $\underline{p}$ is such that $[\kappa q^L - \underline{p}]\Delta - e = 0$.

How do low-quality firms choose between these two prices? Low-quality firms benefit from ratings by earning higher prices in period 2 (point 4). But to get a rating, they have to charge a low price $\underline{p}$ $(< \overline{p})$ in period 1 so that consumers reciprocate with a good rating, which is why we call this strategy 'ratings harvesting'. Alternatively, in period 1 low-quality firms can mimic the high price of high-quality firms $\overline{p}$, and get no ratings and lower profits in period 2. Because firms who follow this strategy copy the price of high-quality firms, we call it

[18] The existence condition captures that κ should be sufficiently large. Intuitively, if κ is too small, consumers believe that firms should get only a very small share of the surplus and never leave a rating. Formal proofs can be found in Appendix A.

[19] Formally, Restriction 2 implies that $\overline{p}$ extracts all conditional expected surplus. Without this restriction, there can be equilibria where the high price is lower than the conditional expected surplus.

'price mimicking'. Thus, low-quality firms trade-off ratings harvesting and price mimicking. The probability that low-quality firms mimic prices and do not receive a rating, δ^*, captures how firms resolve this trade-off in equilibrium. This δ^* also captures the informativeness of ratings: as δ^* increases, low-quality firms obtain a rating less often, and the ratings better help consumers distinguish between high-and low-quality firms.

Why may low-quality firms set $\delta^* \in (\frac{1}{2}, 1)$? Intuitively, low-quality firms harvest ratings to free-ride in the reputation of high-quality firms. This, however, undermines the expected quality associated with a good rating until—in equilibrium—low-quality firms are indifferent between ratings harvesting and price mimicking.[20]

We now explain the impact of reciprocity on low-quality firms' pricing and ratings. To begin, suppose the kindness Δ is sufficiently small such that $\delta^* = 1$ in equilibrium. For a given quality of ratings δ^*, low-quality firms need to offer a discount $\overline{p} - \underline{p}$ to get a good rating; this discount $\overline{p} - \underline{p}$ decreases as Δ increases. Intuitively, when Δ is small, the rating utility $v_1 = [\kappa q^L - p_1^L]\Delta - e$ is quite 'small' and consumers have a low level of intrinsic motivation to leave a good rating. To encourage consumers to rate and compensate them for the cost of ratings e, low-quality firms need to offer a lower price to provide a higher value-for-money for consumers. When Δ is sufficiently small, low-quality firms find it too costly to obtain a rating, so they charge the higher price of $\overline{p}$ with probability $\delta^* = 1$. Because only high-quality firms obtain a rating, ratings perfectly signal quality.

Now suppose Δ increases. As Δ increases, consumers are more inclined to reciprocate a given value-for-money with a rating, which is why the price for which low-quality firms can obtain a good rating, $\underline{p}$, increases. In other words, more kindness (Δ) lowers the opportunity cost of obtaining a good rating. Low-quality firms set the lower price of $\underline{p}$ more often, and obtain a good rating in equilibrium with positive probability.

These arguments explain why reciprocity reduces the quality of ratings: low-quality firms can offer a higher value-for-money to trigger consumers' reciprocity and obtain good ratings. But when low-quality firms start to harvest ratings, both high- and low-quality firms receive good ratings with strictly positive probability, which makes ratings less-informative about product quality. Thus, low-quality firms harvest ratings to trigger the consumers' kindness, but thereby undermine the quality of ratings. The following proposition summarizes this result.

Proposition 2. $\frac{\partial \delta^*}{\partial \Delta} < 0$ *when* (1) *holds, and* $\frac{\partial \delta^*}{\partial \Delta} = 0$ *otherwise.*

[20] In equilibrium, $\delta^* > \frac{1}{2}$, because low-quality firms will only find it profitable to free ride on the reputation of high-quality firms, if their reputation is sufficiently good, i.e. if δ^* is sufficiently large.

When consumers exhibit a larger sense of reciprocity, low-quality firms harvest ratings more frequently. Two clear implications arise form this proposition. First, firms use prices to induce consumers to be kind. Second, when consumers are more reciprocal, ratings become less-informative.

Growing evidence suggests that ratings are influenced not just by quality, but also by prices. More precisely, consumers seem to rate based on the value-for-money they obtain from a purchase. For example, studying marketplaces for digital cameras, Li and Hitt (2010) highlight that a 1% increase in price reduces ratings by 0.36 stars in 5-star ratings and 0.71 stars for 10-star ratings. On AirBnB, Gutt and Kundisch (2016) and Neumann et al. (2018) show that prices negatively impact ratings. On Yelp, Luca and Reshef (2021) provides evidence that a 1% increase in prices leads to a 3-5% decrease in average rating. Abrate et al. (2021) suggests that a 1% increase in hotel prices leads to a decrease of 1 star (out of 10) in overall ratings. Because these articles control for product characteristics, they suggest that it is value-for-money that influences ratings, and not quality alone. Our mechanism explains how both quality and prices affect ratings through reciprocity: consumers perceive a higher value-for-money as a kindness, which they reciprocate with positive ratings.

Our results connect to evidence on rating inflation. Rating inflation is well documented in the literature (Filippas et al., 2022), but not well understood. We offer novel explanations for this phenomenon: low-quality firms lower prices to offer a larger value-for-money and boost their ratings. This benefits these firms, but, in equilibrium, makes ratings less-informative about product quality.

We have shown how reciprocity can impact the informativeness of ratings. We now explore how the design of ratings systems can impact the informativeness of ratings, and ask how beneficial ratings are for consumers.

We restrict the remainder of our analysis to situations where the low-quality firm plays a mixed-strategy, i.e. where (1) holds. First, the condition is satisfied when the difference in quality is sufficiently large, i.e. when ratings are more relevant in the first place. Second, doing so allows us to directly study how changes to the ratings environment impacts the informativeness of ratings, captured by δ^*.

4 Designing ratings environments

In this section, we discuss how common features of a platform, such as the effort needed to leave a rating and the aggregate product quality on a marketplace, influence the informativeness of ratings.

Facilitating ratings

The design of ratings systems can make it easier, or more difficult, to rate. For example, raters may have to complete a verification process, they may be asked to rate along multiple dimensions, or raters may receive monetary rebates and reminders to rate. These design features influence the time and cognitive effort it takes to evaluate a product, and therefore the cost of leaving a rating.

Intuitively, the law of large numbers would suggest that collecting more ratings would lead to more precise and more-informative ratings. From this perspective, reducing the cost of leaving a rating seems to be a good idea. We show that this intuition is misleading as it ignores how firms and consumers respond when ratings become easier.

In our setting, less-costly ratings lead to less-informative ratings. The reason is closely related to reciprocity: if a kind action is less effort, consumers are more inclined to do be kind. Thus, as becomes easier for consumers to rate (i.e. e decreases), firms need to leave less surplus to induce consumers to reciprocate with a good rating.[21] In equilibrium, this encourages especially low-quality firms to harvest ratings: they set $\underline{p}$ with a higher probability $(1 - \delta^*)$, which makes ratings less-informative about quality.

Corollary 1. *If* (1) *holds, then* $\frac{\partial \delta^*}{\partial e} > 0$.

The result suggests that making ratings less costly for consumers, even though it induces more ratings in equilibrium, encourages low-quality firms to harvest ratings and makes ratings less-informative. This provides another channel through which reciprocity-based ratings induces rating inflation: easier ratings encourage especially low-quality firms to harvest ratings. In turn, this means that making ratings costly can make them more-informative.

This result connects well to evidence. Cabral and Li (2015) measure quality using shipping speed. They find that for low-quality products, higher rebates for ratings decrease the proportion of negative ratings. Since rebates offset the cost of rating, their result highlights—as in our model—that lower cost of rating makes ratings less-informative about quality. Lafky (2014) shows that when it becomes more costly to rate, ratings become more extreme. This follows our prediction that it is easier to differentiate between firms when ratings are costly.

Anecdotal evidence suggests that the cost to leave a rating has decreased over time on many

[21] Formally, $\underline{p}$ increases and the difference between $\overline{p}$ and $\underline{p}$ shrinks.

ratings platforms. Yelp and Google encourage ratings with various perks, such as invitations to exclusive events and discount codes.[22] On google reviews, users receive constant reminders to leave ratings and can leave one-click ratings on their smartphone. This trend of fuss-free ratings is also gaining traction on Amazon. Prior to 2020, Amazon required customers to write a review in order to leave a rating, subsequently removing this requirement and allowing for one-click ratings.[23] Publicly, they stated that more feedback would lead to more accurate ratings, relying on the law of large numbers to drown out fake reviews.[24] Our results suggest that Amazon's effort to encourage ratings to make them more-informative may backfire. Although more 'real' customers may be rating, which could solve the problem of fake ratings on Amazon, easier ratings also affect pricing incentives of firms. By reducing the cost to leave a rating, low-quality firms firms find it easier to trigger reciprocity and obtain a good rating, which can ultimately lead to less-informative ratings.

Quality control

We have shown that (i) a stronger sense of reciprocity (Δ), and (ii) lower cost to leave a rating (e) encourage low-quality firms to harvest ratings, triggering rating inflation. In both cases, rating inflation is the result of less-informative ratings. In practice, however, an increase in the average product quality also improves ratings. We now shed light on this scenario and explore how changes in the aggregate quality of sellers in the market affect the informativeness of ratings.

The aggregate quality on a marketplace may change for a variety of reasons. First, low-quality firms may invest in better quality (Klein et al., 2016) or leave the market (Cabral & Hortaçsu, 2010; Nosko & Tadelis, 2015). Second, platforms may pre-screen and weed out low-quality firms to control the quality of firms (Casner, 2020; Nosko & Tadelis, 2015; Wang, 2021). Both channels can improve the aggregate quality on the market and ultimately lead to better average ratings. If firms have higher average quality, however, the incentives of low-quality firms to harvest ratings also changes. This way, better average seller quality may render ratings more- or less-informative.

We show that when the aggregate quality improves (i.e. γ increases), the remaining low-quality firms may harvest more or less ratings, depending on the aggregate quality level of the market.

[22] Yelp Elite Squad and Google Local Guides perks as described by Yelp (Yelp, 2022) and the Harvard Business Review article Donaker et al. (2019).
[23] A timeline of Amazon's rating system as documented by Forbes (Masters, 2021).
[24] As reported by TechCrunch (Perez, 2019).

The starting point to understand this result is that low-quality firms only harvest ratings, when ratings are useful to distinguish seller quality. Intuitively, low-quality firms can only free-ride on the reputation of high-quality firms, when ratings are somewhat useful to distinguish sellers so that high-quality firms indeed have a reputation.

Let us first consider the case where the aggregate quality in the market is low. For simplicity, suppose γ is close to zero. Almost all firms are of low quality, so ratings are somewhat useless to help consumers distinguish sellers. But as γ increases, ratings become more useful, which encourages low-quality firms to harvest more ratings. Thus, for 'small' γ, an increase in the aggregate quality leads to less-informative ratings.

Now consider the opposite scenario where the aggregate quality is high. For simplicity, suppose γ is close to 1. Again, ratings are not useful to distinguish sellers. But as γ increases, they become even less useful to distinguish sellers so that low-quality firms harvest ratings less. This is why for 'large' γ, an increase in the aggregate quality leads to more-informative ratings.

The following proposition summarizes this result.

Proposition 3. *There exists a unique* $\overline{\gamma} \in (0,1)$ *such that* $\frac{\partial \delta^*}{\partial \gamma} < 0 \iff \gamma < \overline{\gamma}$, *and* $\frac{\partial \delta^*}{\partial \gamma} > 0 \iff \gamma > \overline{\gamma}$.[25]

The proposition works out how changes in aggregate quality interacts with the informativeness of ratings. When aggregate quality is low, quality increases make ratings less-informative. But when aggregate quality is high, improvements in quality have a double dividend: aggregate quality increases and ratings become more-informative.

Our result connects with the observation of quality-controls in practice. For example, Amazon actively enforces seller quality, suspending sellers who do not meet a minimum standard.[26] Also Uber has announced that it will remove both riders and drivers with consistently poor ratings,[27] and both Uber and their subsidiary Uber Eats suspend drivers who fall below a minimum rating.[28] Booking.com suspends properties for quality control purposes;[29] Airbnb bans hosts based on a combination of factors, including being in the bottom 1% of

[25] $\overline{\gamma}$ is given by (11).

[26] Amazon makes this decision through a combination of customer reviews, feedback and other measures (Rushdie, 2018; Soper, 2019).

[27] Uber announces that it will begin deactivating riders with poor ratings (Dickey, 2019).

[28] Leaked documents from Uber suggest drivers risk deactivation if they fall below 4.6 stars as reported by TechCrunch (Dickey, 2019). Uber Eats communication with couriers as posted on a forum for drivers (UberLyftDriver, 2017).

[29] Partners report that Booking.com closes their apartments on Booking.com Partner Hub (Prodius, 2020).

overall ratings and guest feedback.[30]

We explain how such measures may affect the informativeness of ratings. First, even though good ratings may not be fully-informative about underlying quality, no ratings or—as we show in an extension—bad ratings are quite informative about low quality.[31] Thus, even in scenarios when good ratings are uninformative, platforms can indeed use bad ratings to weed out low-quality firms. Second, when quality controls make ratings less-informative, that platforms can counter such adverse affects by adjusting the effort to rate accordingly.

5 Surplus Analysis

So far, we studied how reciprocity affects the informativeness of ratings. Conventional wisdom suggests that more-informative ratings help consumers make more-informed purchase decisions and ultimately benefit consumers. We now explore the link between the informativeness of ratings and consumer surplus more carefully. The key insight is that consumer-optimal rating systems are often somewhat, but never fully, informative.

To start, we investigate how ratings harvesting affects consumer surplus. In order to induce consumers to reciprocate, firms need to set a price below the consumers' ex-post willingness to pay. This is why sellers, even though they are monopolists, leave a rent to consumers. To see this rent, we write down the expected consumer surplus

$$CS = (1-\gamma)(1-\delta^*)(q^L(1-\kappa) + \frac{e}{\Delta}). \tag{2}$$

In period 2, and in period 1 when consumers face a high price of $\overline{p}$, firms set prices to extract all conditionally expected consumer surplus. But in period 1 when consumers observe a low price, which happens with probability $(1-\gamma)(1-\delta^*)$, they get the surplus $q^L - \underline{p} = (q^L(1-\kappa) + \frac{e}{\Delta})$. Low-quality firms leave this surplus so that consumers reciprocate with a good rating, allowing low-quality firms to free-ride on the reputation of high-quality firms and charge a higher price in period 2.

We have shown above that low-quality firms harvest ratings and make ratings less-informative. But in order to harvest ratings, low-quality firms need to offer low prices. This is why rating harvesting benefits consumers. This, however, does not imply that consumers prefer un-

[30]Information from Airbnb help center information (Airbnb, 2022) and a third party Airbnb management service (Zodiak, 2021).

[31]In practice, consumers may not rate for various reasons, so that products without ratings are not necessarily low quality. This is why we check that the result also holds in the setting with negative ratings which are informative about low quality.

informative ratings. If ratings were completely uninformative, low-quality firms would not harvest ratings, and consumers would earn no surplus. We now discuss implications of this result more carefully for the impact of rating effort on consumer surplus.

Cost of ratings

A lower cost of ratings (e) has two opposing effects on consumer surplus. First, and following directly from Corollary 1, low-quality firms harvest ratings and charge the low price $\underline{p}$ more often; this tends to increase consumer surplus. Second, however, the level of the low price, $\underline{p}$, increases: when consumers can rate more easily, they are more inclined to reciprocate kindness. This is why low-quality firms who harvest ratings can now charge a higher $\underline{p}$ and still receive a good rating, reducing consumer surplus. Overall, because easier ratings encourage low-quality firms to harvest ratings, they harvest ratings more often, which tends to benefit consumers. But low-quality firms do so with a higher price, which tends to harm consumers.

We show that these two opposing effects pin down a positive level of ratings effort that maximizes consumer surplus.[32]

Proposition 4. *There exists a level of effort $e^{cs} > 0$ that maximizes consumer surplus. At this level of effort, $\delta^* \in (\frac{1}{2}, 1)$. This is true if*

$$(1-\gamma)^2\gamma(q^H - q^L)^2 \geq (1+\gamma)^2(q^L(1-\kappa) + \frac{e}{\Delta})^2. \tag{3}$$

Otherwise, consumers prefer $e^{cs} = 0$.

The proposition characterizes when the conventional wisdom that more-informative ratings benefit consumers is true. When e is sufficiently small ($e < e^{cs}$), making it more costly to rate leads to more-informative ratings (Corollary 1), and increases consumer surplus. In this case, the price effect on $\underline{p}$ dominates and more-informative ratings put pressure on prices for low-quality firms.

More surprisingly, when e is sufficiently large ($e \geq e^{cs}$), more-informative ratings harm consumers. Intuitively, when e is large, low-quality firms charge a very low $\underline{p}$ to harvest ratings. This is why, as e increases further, low-quality firms get discouraged from harvesting ratings, which reduces consumer surplus.

[32] Note that if we would incorporate rating utility into consumer surplus, consumers would get an additional benefit and cost from rating, so the consumer optimal level of effort could be higher or lower. But crucially, it can still be positive.

A key implication of the Proposition is that even though consumers benefit when low-quality firms harvest ratings, consumers still prefer a somewhat-informative rating system. The reason is that low-quality firms are only willing to harvest ratings if they can free-ride on the good reputation of high-quality firms; but this requires ratings to be somewhat-informative.

By condition (3) consumers prefer somewhat-informative ratings if the difference between high- and low-quality firms is sufficiently large. This is similar in spirit to (1) and rather intuitive: if the condition is violated and the difference in quality is small, then the price difference in period 2 is also small. Low-quality firms have little incentive to harvest ratings and hardly ever do so. Because low-quality firms harvest ratings so rarely, consumers want firms to harvest ratings more often and prefer $e^{cs} = 0$. This result, however, seems economically less relevant, since it only applies when the quality differences are small so that ratings are less relevant in the first place.

We now explore the impact of costly ratings on seller surplus. While buyers prefer somewhat-informative ratings, sellers on average prefer uninformative ratings. Intuitively, seller surplus is largest when sellers leave the smallest reciprocity rent to buyers. This is true when $e = 0$ and ratings are least-informative. In this case. low-quality firms have the highest incentive to harvest ratings, but face the smallest opportunity cost for doing so.

While sellers on average prefer a small e and less-informative ratings, high-quality firms prefer a large e and perfectly-informative ratings: informative ratings allow high-quality firms to distinguish themselves from low-quality firms who try to free-ride on their reputation. As e increases, this free-riding becomes more costly, which leads to more-informative ratings and allows high-quality firms to extract more of the surplus they generate. The following corollary summarizes these results.

Corollary 2. *When* (3) *holds, average seller surplus is maximal at* $e^s = 0$ $(< e^{cs})$. *Moreover, profits of high-quality firms increases in* e*, and profits of low-quality firms decreases in* e*.*

The corollary implies that only high-quality firms unambiguously prefer perfectly-informative ratings, because this limits free-riding on their reputation. Neither buyers nor sellers, on average, prefer perfectly-informative ratings. But buyers prefer more-informative ratings than the average seller. The reason is that somewhat-informative ratings push sellers to harvest ratings, which puts pressure on prices. This suggests that the aforementioned efforts of Google reviews and Amazon to facilitate and encourage ratings might not just lead to less-informative ratings, but also harm consumers through higher prices. They do, however, benefit sellers.

Quality controls

We now discuss the effect of aggregate product quality on consumer surplus. Our first insight is that improvements in aggregate quality can make consumers worse off.

The intuition has two steps. First, we know from Proposition 3 that low-quality firms harvest ratings when they can free-ride on the reputation of high-quality firms. Thus, when γ is large and there are more high-quality firms to free-ride on, an individual low-quality firm harvests ratings more and benefits consumers. On the other hand, only low-quality firms harvest ratings and leave reciprocity rent to consumers, suggesting consumers benefit when γ is sufficiently small. As a result of these opposing forces, consumer surplus is concave in γ and an intermediate $\gamma^{cs} \in (0, 1)$ maximizes consumer surplus.

The second key insight resembles a previous one on the cost of ratings: consumers prefer quality levels that lead to somewhat-informative ratings ($\gamma^{cs} < \overline{\gamma}$, where $\overline{\gamma}$ is the same defined in Proposition 3), but not fully-informative ratings ($\gamma^{cs} \to 1$). The intuition is familiar from above: with somewhat-informative ratings, low-quality firms harvest ratings, which puts pressure on prices.

The next proposition summarizes these results.

Proposition 5. *Equilibrium consumer surplus is strictly concave in γ. There exists an aggregate quality level, denoted by γ^{cs}, that maximises consumer surplus, where $\overline{\gamma} > \gamma^{cs}$ and $\gamma^{cs} > 0$.*

Proposition 5 implies that, even when larger aggregate quality leads to more-informative ratings, consumers can be worse off. This is the case when $\gamma \notin [\gamma^{cs}, \overline{\gamma}]$. For $\gamma < \gamma^{cs}$, better quality encourages low-quality firms to harvest ratings, which benefits consumers but undermines the informativeness of ratings. For $\gamma > \overline{\gamma}$, an increase in aggregate quality makes ratings more-informative; but as low-quality firms participate in less ratings harvesting, consumers surplus diminishes. Thus, to evaluate a rating system, observing that ratings reflect quality more closely is not enough to conclude that consumers benefit.

Sellers unambiguously benefit if their average quality increases. High-quality firms are able to set higher prices in both periods. Low-quality firms benefit either from being able to set a higher price in the first period when they mimic prices, or from setting a higher price in the second period when they harvest ratings.

Lemma 1. *The profits of high- and low-quality firms increases in γ. Seller surplus is maximised at $\gamma^s \to 1$*

Because all firms benefit from a higher average quality, this also implies that (remaining) firms prefer a higher level of quality controls than consumers. Together with Proposition 3, Lemma 1 implies that sellers prefer ratings that are uninformative. Additionally, when considering Proposition 5, Lemma 1 suggests that firms prefer ratings that are less-informative than what consumers prefer. The intuition is familiar from above: firms on average prefer uninformative ratings, and consumers prefer somewhat-informative ratings. Hence, firms prefer ratings that are less-informative than consumers.

6 Extensions and Robustness

Designing a profit maximising ratings system. In the main text, we take the properties of a rating system as given. But in this extension, we explore how a two-sided platform designs its rating system. The platform needs to offer value to both consumers and firms to get them to use the platform and generate transactions. To do so, the platform sets a royalty to sellers, and chooses how easy consumers can rate (through e, e.g. by allowing one-click ratings or by sending reminders). We show that platforms may choose a very low e and induce a rather uninformative rating system when it favors sellers; but it may also design informative rating systems when it cares more about attracting consumers. This result speaks towards concerns that the design of rating systems are insufficiently informative for consumers Competition and Markets Authority (UK), 2017. We also discuss how platform's strategic choices may change over time, i.e. they may start with an informative rating system to attract buyers, but then facilitate ratings and accept less informative ratings to extract more profits from sellers. This reflects the ever changing rating system on Amazon, from introducing new verification methods to allowing ratings to be provided without reviews Amazon, 2021. For details, see Web Appendix B.1.1.

Competitive environment. We study how competing firms use ratings and introduce a competitive fringe who sells a product of known quality, at a price equal to its marginal cost c. We show that when c decreases and competition gets more fierce, low-quality firms participate in more ratings harvesting, and ratings become less-informative. Despite less-informative ratings, competition exerts pressure on all firms, which respond by lowering prices, benefiting consumers. For details, see Web Appendix B.1.2.+

Negative ratings. We relax our simplifying assumption and allow for negative ratings—in addition to positive ratings and no ratings. In equilibrium, negative ratings arise from retaliation (negative reciprocity). When firms leave a sufficiently small surplus to consumers,

consumers perceive this as unkind and respond with an unkindness, retaliating with a bad rating. In equilibrium, only low-quality firms receive negative ratings, which is why negative ratings transmit the same information as no ratings in the main model, and our results are qualitatively robust.[33] But—different from the main model—ratings are more extreme.[34] For details, see Web Appendix B.1.3.

Continuum of Firms. We also show that our results extend beyond firms with two types and study a continuum of firms with different quality types. We find a pure-strategy equilibrium where (i) an interval of highest quality firms gets a good rating; (ii) an interval of lowest quality firms gets a bad rating, and (iii) a middle interval of firms harvests ratings and gets a good rating as well. In this equilibrium, middle-quality firms harvest ratings and make ratings less-informative. Additionally, as ratings become easier (e decreases),the middle interval of firms that harvest ratings grows, leading to less-informative ratings as in the main model. For details, see Appendix Web Appendix B.1.4.

Longer Horizon Model. We show that our results are robust to more than two periods by looking at a three period model. We find equilibria that are similar to those described in our base model, and show that low-quality firms harvest ratings and mimic prices with strictly positive probability in every non-terminal period. Interestingly, and in line with evidence by Cabral and Hortaçsu (2010) and Jin and Kato (2006), low-quality firms are less likely to sustain a good rating. For details, see Web Appendix B.1.5.

7 Related Literature

Our key results connect **evidence on ratings.** Ratings aid consumers by reducing uncertainty about the quality of the product. Much of the literature suggests that ratings do indeed signal quality on major platforms like eBay (Hui et al., 2021), Taobao (Zhang et al., 2012), and Airbnb (Proserpio et al., 2018). The broader empirical literature, however, suggests that other factors also influence ratings (Gao et al., 2018; Masterov et al., 2015; Nosko & Tadelis, 2015; Zervas et al., 2021).

[33] Fradkin and Holtz (2022) show that paying guests of hosts without ratings to rate leads to more negative reviews. In line with this, consumers who do not rate are more likely to have had a low-quality product, so encouraging them to rate when negative ratings are possible leads to more negative ratings.

[34] When consumers exhibit biased reciprocity, that is the warm glow they receive from leaving a good rating exceeds the warm glow they receive from leaving a bad rating, our result provides theoretical support for suggestions by Dellarocas and Wood (2008) and Filippas and Horton (2022) that reciprocity bias leads to a J-shaped ratings distribution, i.e. extreme ratings where negative ratings are less common than good ratings.

Many studies have shown that prices have a significant influence on ratings. The evidence highlights two key patterns. First, for a given quality, lower prices induce better ratings (Cai et al., 2014; Carnehl et al., 2021; Li & Hitt, 2010; Luca & Reshef, 2021; Neumann et al., 2018). Second, firms with better ratings charge higher prices in the future, a pattern frequently referred to as 'rating harvesting' (Cabral & Hortaçsu, 2010; Cabral & Li, 2015; Cai et al., 2014; Carnehl et al., 2021; Ert & Fleischer, 2019; Gutt & Herrmann, 2015; Jin & Kato, 2006; Jolivet et al., 2016; Lewis & Zervas, 2019; Li et al., 2020; Livingston, 2005; Luca & Reshef, 2021; McDonald & Slawson, 2002; Neumann et al., 2018; Proserpio et al., 2018). We can explain both of these patterns in a single framework, i.e. low-quality firms charge lower prices to induce consumers to reciprocate with a good rating. Firms harvest these good ratings by charging higher prices in the future.

We also contribute to the **literature on reciprocity in ratings**. A series of empirical articles argue that reciprocity is a key driver of rating behavior, (Cabral & Li, 2015; Diekmann et al., 2014; Fradkin et al., 2021; Li & Xiao, 2014; Zervas et al., 2021). Some experimental work directly identifies that reciprocity drives rating behavior (Bolton et al., 2013; Halliday & Lafky, 2019; Lafky, 2014). Taken together, these experiments suggest: (i) reciprocity biases ratings upward in mutual-rating systems where buyers and sellers rate each other. But double-blind feedback strongly reduces this bias. Also following the work of Dellarocas and Wood (2008) and others on eBay, most online marketplaces adopted a double-blind approach to feedback, which is why we do not look at mutual-rating systems. (ii) Also with one-sided or double-blind rating systems, sellers take advantage of their ability to influence ratings, and they use prices to do so. We contribute to this literature by modelling how sellers use prices to trigger reciprocity and thereby influence ratings. By doing so, we derive novel predictions on how reciprocity causes rating inflation, namely that reciprocity induces ratings harvesting, reciprocity makes ratings less-informative, and that encouraging consumers to rate (e.g. through one-click ratings or reminders to rate) can backfire by making ratings less-informative.

We also connect to the ongoing **debate on rating inflation**. Rating inflation describes the observation that rating scores improve over time, and most of the improvements cannot be attributed to product quality (Filippas & Horton, 2022; Filippas et al., 2022; Nosko & Tadelis, 2015; Zervas et al., 2021).[35] We propose multiple channels through which reciprocity

[35] In particular, Nosko and Tadelis (2015) study the binary rating environment on eBay and find that more than 99% of ratings are positive. Filippas and Horton (2022) study a marketplace that kept ratings unpublished at first and then started to publish ratings. Once ratings were published, they got better. This is in line with our mechanism: consumers can only reciprocate a good value-for-money once ratings are published, so our mechanism predicts more rating harvesting and therefore rating inflation once ratings are published.

leads to more rating harvesting and therefore rating inflation: (i) platforms encouraging consumers to rate, (ii) increased quality controls by platforms, and (iii) increased competition between sellers.[36]

We provide a theoretical explanation for why identical products may get **different ratings across platforms** (Chevalier & Mayzlin, 2006). Some evidence suggests that this is due to user self-selection onto marketplaces (Granados et al., 2012; Raval, 2020). We provide a complementary explanation and show that differences in features of the rating system (e.g. cost of ratings, aggregate quality, competition between sellers) can lead to different ratings for identical products. Our results align with experimental evidence on how the design of rating systems can influence ratings (Schneider et al., 2021).

We connect to the wider theoretical literature on **trust and information transmission in the digital economy**. Platforms may recommend products (Hagiu & Jullien, 2011; Peitz & Sobolev, 2022), shroud additional fees and features of third-party sellers (Johnen & Somogyi, 2021), and marketplaces may have fake reviews (He et al., 2022). We contribute to this literature by studying information transmission via ratings and study how firms can use prices to affect their own ratings.

We closely connect to the **theoretical literature on reputation** (e.g. Cabral (2000), Jullien and Park (2014), Kovbasyuk and Spagnolo (2021), Martin and Shelegia (2021), and Tadelis (1999); see also Bar-Isaac and Tadelis (2008) for a survey), and **word-of-mouth** (Chakraborty et al. (2022)). In existing work usually (i) buyers do not endogenously choose if and how to rate, and (ii) ratings mostly reflect quality and are independent of price. While some papers relax some of these assumptions (e.g. Chakraborty et al. (2022) relax (i), Sobolev et al. (2021) and Stenzel et al. (2020) relax (ii)), no article seems to feature that buyers choose if and how to rate strategically, and prices influence ratings. We capture both of these features, which allows us to capture empirical patterns of prices and ratings we discuss earlier in this section.

Martin and Shelegia (2021) study a signalling model where consumers leave a good rating if the product was better than expected. Initially, high-quality sellers offer a lower price to overdeliver to get a good rating. In contrast, we show how low-quality firms use prices to improve their ratings.

Some recent papers study the impact of **value-for-money ratings**. Stenzel et al. (2020)

[36] Research on information systems propose that social norm of good ratings increases over time (Qiu et al., 2012). Our mechanism can illustrate how social norms changed the way they did: platforms encourage consumers to rate (lowering e and/or raising Δ), which leads to a new equilibrium where reciprocity plays a more important role and ratings increase.

focus on prices in the long-run equilibria. Instead, we focus on short-term intertemporal trade-offs and derive novel dynamic effects like rating harvesting in our framework.Sobolev et al. (2021) start with the premise that more sales can lead to more or less informative ratings. The key novelty in our setting is that we endogenize consumers choices of if and whom to rate. To do so, we use a well-established theory of reciprocity. In our setting this endogenous choice implies that sellers trade-off ratings harvesting and price mimicking, and leads to different comparative statics for how the cost of rating or aggregate quality affect ratings.

Some researchers argue that consumers should be **paid to rate**. One argument is that sellers should be allowed to pay for feedback, because only high-quality firms are willing to pay for feedback, making this a credible signal (Halliday & Lafky, 2019; Kihlstrom & Riordan, 1984; Milgrom & Roberts, 1986; Nelson, 1974). Others argue that feedback is like a public good that is underprovided (Avery et al., 1999; Bolton et al., 2004; Chen et al., 2010). In contrast, we show that encouraging ratings from all consumers (e.g. when marketplaces pay consumers to rate, introduce simpler one-click ratings, or reminding consumers to rate) encourages low-quality firms to harvest ratings, leading possibly to more ratings, but also less-informative ratings. This is in line with evidence by Cabral and Li (2015) and Lafky (2014) that we discussed above.

We connect to the literature on **consumer information about differentiated** products. A wide range of articles highlight how firms prefer well-informed consumers to amplify product differentiation and relax competition (Anderson & Renault, 2006; Armstrong & Zhou, 2022; Hefti et al., 2022; Johnen & Leung, 2022). Indeed, Armstrong and Zhou (2022) show that firms prefer more-informative information structures than consumers. We show that this intuition may not translate to the context of ratings: When firms harvest ratings, they may prefer less-informative ratings than consumers.

We also connect to recent work by Rhodes and Wilson (2018) on **false advertising**. Low-quality firms falsely advertise high quality to free-ride on the reputation of high-quality firms. Also in our setting, low-quality firms free-ride on the reputation of others and undermine information transmission. But our mechanism is very different. In contrast to ads, firms in our setting do not choose their own ratings, but need to charge a low price to trigger reciprocity and get a good rating. This leads to novel and inherently dynamic effects like rating harvesting.

8 Conclusion

Ratings are an essential element of the online economy, building trust between strangers. But ratings are only able to build trust if they are informative about the underlying products and services. In this paper, we use a model of consumer reciprocity to study how firms use prices to influence their own ratings. We explore a qualitatively novel trade-off between rating harvesting and price mimicking, which connects well to evidence on the dynamic interaction between prices and ratings. We identify several factors that encourage rating harvesting and lead to less-informative ratings. We also explore implications for buyer and seller surplus.

In practice, consumers may also read product reviews of previous customers. In principle, these reviews could help consumers disentangle how quality and price affect ratings. But we argue that reviews do not solve the problem. First, even if consumers take the time it takes to read reviews, they will only read a small and selected sample of user experience. Second, even reviews that comment on value-for-money rarely mention the exact price they paid, which makes it impossible to judge relative to which price the value was good.

The key feature of our analysis is that consumers need to obtain a sufficiently high value-for-money to leave a good rating. But consumers may rate for other reasons, e.g. to help other consumers by signalling product quality through ratings, or because they are intrinsically motivated to reveal the true quality of the product. In these motivations, however, ratings are not affected by price. Thus, even if some consumers have such other motivations, we would still expect price dynamics resembling rating harvesting, as long as at least some consumers rate based on their value-for-money.

In practice, fake ratings also undermine how informative ratings are. If low-quality firms are somewhat more inclined to acquire fake ratings, fake ratings will also make ratings less-informative of quality. In contrast, firms in our setting use lower prices to get better reviews, which benefits consumers and can explain evidence that lower prices induce better ratings.

Many platforms give consumers easy access to past ratings, but do not connect them to the prices that the raters paid.[37] This feature of many rating environments is a key reason, in our setting, why consumers cannot distinguish whether a given rating is the result of high quality, or a low price. If ratings, however, would reflect purchase prices, consumers may be

[37] For example, platforms such as Amazon do not reveal past prices to consumers on their listings, nor do they reveal which price a rater paid. While there exist third party websites such as https://camelcamelcamel.com/ and https://keepa.com/ that track past prices on Amazon, such websites do not link prices to actual sales and reviews, so they do not allow users to infer if prices influenced ratings.

better able to identify high-quality firms, which could discourage rating harvesting. We do, however, leave this and other questions for future research.

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Appendix A Proofs

Proof of Proposition 1

We proceed as follows. First, we pin down equilibrium prices in period 1 in Lemma 2 and equilibrium beliefs in Lemma 3. Afterwards, we use these lemmas to prove the remaining statements in Proposition 1.

Lemma 2. *In equilibrium, firm j plays the price p^j_{t,R_t} in period t, in order to receive the rating R_t.*

In the first period, firms play the following equilibrium prices with positive probability.

- *High-quality firm:* $p^H_{1,1} = min\{\kappa q^H - \frac{e}{\Delta},\ E[q_1|R_0, p^H_{1,1}]\}$
- *Low-quality firm:*

$$p^L_{1,1} = \kappa q^L - \frac{e}{\Delta}$$

$$p^L_{1,0} = E[q_1|R_0, p^H_{1,1}]$$

Proof of Lemma 2.
We proceed in three steps. First, we consider the pricing strategy of the high-quality firms. Second, we look at the pricing strategy of low-quality firms receiving a rating. Third, we focus on prices of low-quality firms obtaining no rating.

To start, we look at the pricing strategy of high-quality firms. We show that their pricing strategy is unique and $p^H_{1,1} = \min\{\kappa q^H - \frac{e}{\Delta},\ E[q_1|R_0, p^H_{1,1}]\}$ with probability 1.

Given Restriction 1, we focus on equilibria where the high-quality firm sets a price which allows it to obtain a rating, $R_1 = 1$. Therefore, in equilibrium, the firm does not consider the pricing strategy that obtains no rating.

We show that high-quality firms set a unique price in period 1 with probability 1. Suppose towards a contradiction that high-quality firms set more than one price with positive probability.

Without loss of generality, suppose that the high-quality firm sets a distribution of prices, $p \in [p', p'']$ such that $p'' > p'$, and the firm receives a rating $R_1 = 1$ with probability 1 for all $p \in [p', p'']$. Therefore, at all $p \in [p', p'']$, consumers purchase products with probability 1.

Notice that for any price $\hat{p} \in [p', p'']$ such that $\hat{p} > p$, we have $\pi^H(\hat{p}) > \pi^H(p)$. To see this, observe that both prices induce the same demand in period 1, but $\hat{p}$ induces a larger margin and therefore strictly larger profits in period 1. Further, both prices induce $R_1 = 1$ with probability 1, and therefore the same expected profits in period 2. As a result, $\pi^H(\hat{p}) > \pi^H(p)$. Shifting the probability mass of the entire price distribution in period 1 to one mass point, p'', strictly increases profits for the high-quality firm, contradicting that the firm sets more than one price with positive probability. Essentially, the same argument implies that the high-quality firm does not set more than one price with strictly positive probability. We conclude that the high-quality firm sets a unique price in period 1 with probability 1.

Next, we prove that there exist an upper bound on prices, $\overline{p_t^j}$ for $j \in \{L, H\}$ such that a firm j receives a rating. In order for a firm to induce a rating, the rating utility must be weakly positive, i.e. $v_t \geq 0$. Therefore,

$$[\kappa q^j - p_{t,1}^j]\Delta - e \geq 0 \Leftrightarrow p_{t,1}^j \leq \overline{p_t^j} \equiv \kappa q^j - \frac{e}{\Delta}.$$

Therefore, the upper bound on prices such that the high-quality firm receives a positive rating is $\overline{p_1^H} = \kappa q^H - \frac{e}{\Delta}$.

Finally, consider that this upper bound is restricted by consumer's beliefs, $E[q_1|R_0, p_{1,1}^H] < \overline{p_1^H}$. Under such scenarios, by Restriction 1, high-quality firms prefer obtaining a rating. This can only be achieved if consumers buy. Therefore, $p_{1,1}^H$ has an upper bound of $E[q_1|R_0, p_{1,1}^H]$.

We next show that $p_{1,1}^H = \min\{\kappa q^H - \frac{e}{\Delta}, E[q_1|R_0, p_{1,1}^H]\}$ with probability 1. To see this, note that $\overline{p_1^L} = \kappa q^L - \frac{e}{\Delta}$ is the cut-off price above which the low-quality firm receives no rating. See also that $\overline{p_1^H} > \overline{p_1^L}$ and $q_L > \overline{p_1^L}$. Thus, because $E[q_1|R_0, p_{1,1}^H] \geq q_L$, the high-quality firm sets its equilibrium price in period 1 strictly above $\overline{p_1^L}$, i.e. $p_{1,1}^H > \overline{p_1^L}$. By Restriction 2, consumers have the same beliefs for all prices strictly above $\overline{p_1^L}$, and since $p_{1,1}^H > \overline{p_1^L}$, these beliefs are the correct equilibrium beliefs $E[q_1|R_0, p_{1,1}^H]$. Because consumers have the same beliefs $E[q_1|R_0, p_{1,1}^H]$ for all prices above $\overline{p_1^L}$, the high-quality firm optimally sets the largest price for which consumers purchase and rate with probability 1, which is $p_{1,1}^H = \min\{\kappa q^H - \frac{e}{\Delta}, E[q_1|R_0, p_{1,1}^H]\}$.

We conclude that high-quality firms set a unique price $p_{1,1}^H = \min\{\kappa q^H - \frac{e}{\Delta}, E[q_1|R_0, p_{1,1}^H]\}$ with probability 1.

We now proceed to the second step and characterize the pricing strategy of low-quality firms who receive a rating. First, we show that the price which it sets and receives a rating is unique. Then, that $p_{1,1}^L = \kappa q^L - \frac{e}{\Delta}$.

Essentially the same argument as used for high-quality firms implies that—conditional on obtaining a rating—the low-quality firm sets a single price with probability 1.

By definition of $\overline{p_1^L}$, $\overline{p_1^L} = \kappa q^L - \frac{e}{\Delta}$. Since this is strictly less than q^L, and since consumers beliefs must be weakly above q^L, consumers are always willing to buy at any price weakly below $\overline{p_1^L}$. Since demand and ratings are the same for all prices weakly below $\overline{p_1^L}$, a low-quality firm that obtains a rating must optimally set $\overline{p_1^L}$ with probability 1. We conclude that conditional on obtaining a rating—the low-quality firm sets $\overline{p_1^L}$ with probability 1.

We now proceed to the third step of the proof and determine prices of low-quality firms who obtain no rating. We show that low-quality firms who obtain no rating optimally set $E[q_1|R_0, p_{1,1}^H]$. We have shown in step 2 that all prices above $\overline{p_1^L}$ induce the same beliefs $E[q_1|R_0, p_{1,1}^H]$. Thus, low-quality firms who obtain a no rating optimally set the highest possible price, $E[q_1|R_0, p_{1,1}^H]$ with probability 1.

This concludes the proof. $\square$

Lemma 3. *In the first period, consumer's beliefs for each equilibrium price p_1 is given by*

$$E[q_1|p_1] = \begin{cases} \frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)} & \text{if } p_1 > \overline{p_1^L} \\ q^L & \text{if } p_1 \leq \overline{p_1^L}, \end{cases}$$

and in the second period,

$$E[q_2|R_1] = \begin{cases} \frac{\gamma q^H + (1-\delta^*)(1-\gamma)q^L}{\gamma + (1-\delta^*)(1-\gamma)} & \text{if } R_1 = 1 \\ q^L & \text{if } R_1 = 0. \end{cases}$$

Proof of Lemma 3.

We prove this Lemma by constructing expected quality using Bayes rule. We start by considering the second period, followed by the first period.

Before we begin, note that by Lemma 2, high-quality firms charge $p_{1,1}^H$ and obtain a rating with probability 1, and low-quality firms obtain a rating if and only if they charge a low price $p_{1,1}^L$. We denote the probability δ as the probability with which low-quality firms charge $p_{1,0}^L$. Thus, $(1 - \delta^*)$ is the probability which the low-quality firm obtains a good rating.

Now consider the second period. Given the consumer's information set in the second period, they are aware of historical ratings R_1, and current prices, p_2. We now show that expected quality in period 2 is independent of second period prices, p_2. Since period 2 is the final period, no firm obtains a rating, which, by Restriction 2, implies that the expected quality in period 2 is independent of second period prices. We conclude that expected quality in period 2 only depends on past ratings, R_1.

Next, we pin down consumers' expectations in period 2. In equilibrium, consumers observe $R_1 = 1$ from all high-quality firms and low-quality firms with low prices, i.e. with probability $\gamma + (1-\delta^*)(1-\gamma)$. Because only low-quality firms get no rating, the expected quality after observing $R_1 = 0$ is q^L. Thus, applying Bayes rule leads to

$$E[q_2|R_1] = \begin{cases} \frac{\gamma q^H + (1-\delta^*)(1-\gamma)q^L}{\gamma + (1-\delta^*)(1-\gamma)} & \text{if } R_1 = 1 \\ q^L & \text{if } R_1 = 0. \end{cases}$$

We now consider the first period. First, recall that $R_0 = 0$.

We distinguish two cases, (i) $p_{1,1}^H = \min\{\kappa q^H - \frac{e}{\Delta}, E[q_1|R_0, p_{1,1}^H]\} = E[q_1|R_0, p_{1,1}^H]$ and (ii) $p_{1,1}^H = \min\{\kappa q^H - \frac{e}{\Delta}, E[q_1|R_0, p_{1,1}^H]\} = \kappa q^H - \frac{e}{\Delta}$.

We start with case (i) and suppose $p_{1,1}^H = \min\{\kappa q^H - \frac{e}{\Delta}, E[q_1|R_0, p_{1,1}^H]\} = E[q_1|R_0, p_{1,1}^H]$. Then by Lemma 2, we have $p_{1,0}^L = p_{1,1}^H$ and $p_{1,1}^L = \kappa q^L - \frac{e}{\Delta}$. Applying Bayes rule leads to

$$E[q_1|p_1] = \begin{cases} \frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)} & \text{if } p_1 = p_{1,1}^H \\ q^L & \text{if } p_1 = p_{1,1}^L. \end{cases}$$

Now consider case (ii) and suppose $p_{1,1}^H = \min\{\kappa q^H - \frac{e}{\Delta}, E[q_1|R_0, p_{1,1}^H]\} = \kappa q^H - \frac{e}{\Delta}$. Then $p_{1,1}^H \neq p_{1,0}^L$, and Bayes rule implies $E[q_1|R_0, p_{1,1}^H] = q^H$. This is only consistent with the finding in Lemma 2 that $p_{1,0}^L = E[q_1|R_0, p_{1,1}^H] = q^H$ if $\delta^* = 0$, i.e. the low-quality firm sets $p_{1,0}^L$ with probability zero. Thus, beliefs are given again by

$$E[q_1|p_1] = \begin{cases} \frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)} & \text{if } p_1 = p_{1,1}^H \\ q^L & \text{if } p_1 = p_{1,1}^L, \end{cases}$$

applied at $\delta^* = 0$. We conclude from cases (i) and (ii) that for equilibrium prices in period 1, beliefs are given by

$$E[q_1|p_1] = \begin{cases} \frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)} & \text{if } p_1 = p_{1,1}^H \\ q^L & \text{if } p_1 = p_{1,1}^L. \end{cases}$$

Because $p_{1,1}^H > \overline{p_1^L}$, $p_{1,0}^L > \overline{p_1^L}$, and $p_{1,1}^L \leq \overline{p_1^L}$, this concludes the proof. □

We prove a slightly more general statement than **Proposition 1**.

Proposition 6. *All perfect Bayesian equilibria satisfy the following. In period 1:*

1. *High-quality firms receive a good rating with probability 1 and charge* $\overline{p} \equiv E[q_1|R_0, p^H_{1,1}]$.

2. *Low-quality firms randomize their strategy.*

   a. *They charge* $\overline{p}$ *and obtain no rating with probability* δ^*.

   b. *They charge* $\underline{p} \equiv \kappa q^L - \frac{e}{\Delta}$ *and obtain a good rating with probability* $1 - \delta^*$.

3. *Consumers beliefs of equilibrium prices are given by*
$$E[q_1|p_1] = \begin{cases} \frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)} & \text{if } p_1 > \kappa q^L - \frac{e}{\Delta} \\ q^L & \text{if } p_1 \leq \kappa q^L - \frac{e}{\Delta} \end{cases}.$$

In period 2:

4. *Prices are equal to expected quality conditional on ratings.*

5. *Consumer beliefs are given by* $E[q_2|R_1] = \begin{cases} \frac{\gamma q^H + (1-\delta^*)(1-\gamma)q^L}{\gamma + (1-\delta^*)(1-\gamma)} & \text{if } R_1 = 1 \\ q^L & \text{if } R_1 = 0 \end{cases}$.

The equilibrium is unique up to off-equilibrium-path beliefs. $\delta^* = 1$ *if and only if* $\kappa q^L - \frac{e}{\Delta} + q^H \leq \gamma q^H + (1-\gamma)q^L + q^L$, *and* $\delta^* \in (\frac{1}{2}, 1)$ *otherwise. The equilibrium exists if* $\kappa q^H - \frac{e}{\Delta} \geq \frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)}$.

Proposition 1 in the main text is obtained as a special case.

Proof of Proposition 6.
From Lemma 2 and 3, we have shown statements 2, 3 and 5. Hence, what remains is to prove statement 1 and 4, as well as existence and uniqueness up to off-equilibrium-path beliefs.

To prove statement 1, note that by Lemma 2, we know $p^H_{1,1} = \min\{\kappa q^H - \frac{e}{\Delta}, E[q_1|R_0, p^H_{1,1}]\}$, and it remains to show that $\min\{\kappa q^H - \frac{e}{\Delta}, E[q_1|R_0, p^H_{1,1}]\} = E[q_1|R_0, p^H_{1,1}]$. Suppose towards a contradiction that $\min\{\kappa q^H - \frac{e}{\Delta}, E[q_1|R_0, p^H_{1,1}]\} = \kappa q^H - \frac{e}{\Delta}$. As we argued in the proof of Lemma 3, we then have $p^H_1 \neq p^L_{1,0}$, and $E[q_1|R_0, p^H_{1,1}] = q^H$, and $p^L_{1,0} = E[q_1|R_0, p^H_{1,1}] = q^H$ is played with probability $\delta^* = 0$. Because the low-quality firm charges $p^L_{1,1} = \kappa q^L - \frac{e}{\Delta}$ with probability 1, all firms get a rating with probability 1. By Lemma 3, low-quality firms earn up to $\kappa q^L - \frac{e}{\Delta} + \gamma q^H + (1-\gamma)q^L$. Low-quality firms can strictly increase profits by charging a first period price of q^H. By Restriction 2, consumers believe $E[q_1|R_0, p_1] = q^H$ for all prices $p_1 \geq \kappa q^L - \frac{e}{\Delta}$, so they purchase in period 1. In period 2, the deviation earns q^L. Overall, the deviation earns $q^H + q^L$. Since $q^H \geq \gamma q^H + (1-\gamma)q^L$ and $q^L > \kappa q^L - \frac{e}{\Delta}$, this deviation profitable for low-quality firms, a contradiction.

We conclude that $p^H_{1,1} = \min\{\kappa q^H - \frac{e}{\Delta}, E[q_1|R_0, p^H_{1,1}]\} = E[q_1|R_0, p^H_{1,1}]$, which proves statement 1. Because we have shown that $p^H_{1,1} = E[q_1|R_0, p^H_{1,1}]$, and this is the same as $p^L_{1,0}$, to simplify notation, we state that $\overline{p} = p^H_{1,1} = p^L_{1,0} = E[q_1|R_0, \overline{p}]$. To further simplify notation, we label $\underline{p} = p^L_{1,1} = \kappa q^L - \frac{e}{\Delta}$.

We now prove statement 4. We have shown in Lemma 3 that in period 2, firms are no longer incentivized by future ratings. We have also shown that consumers' beliefs only depend on past ratings. Thus, firms optimally charge prices equal to the expected profits conditional on the past ratings they received. We conclude that in period 2, prices equal expected quality conditional on ratings, which proofs statement 4.

We conclude that statements 1 - 5 hold.

We now show that equilibria are unique up to off-equilibrium-path beliefs. To show uniqueness of equilibrium, consider that for some δ^*, low-quality firms are indifferent between getting a rating and no rating. From the proof of statement 1, we know that in equilibrium we must have $\delta^* < 1$ and $\kappa q^H - \frac{e}{\Delta} > E[q_1|p^H_{1,1}]$, implying that $\overline{p} = \frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)}$.

Charging $\underline{p} = q^L - \frac{e}{\Delta}$ induces a rating and, given correct equilibrium beliefs, the following is the total profits for the low-quality firm:

$$\kappa q^L - \frac{e}{\Delta} + \frac{\gamma q^H + (1-\delta^*)(1-\gamma)q^L}{\gamma + (1-\delta^*)(1-\gamma)}. \tag{4}$$

This is strictly increasing in δ^* for all $\gamma \in (0,1)$ and $q^H > q^L$.

When the low-quality firm charges $\overline{p} = \frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)}$ in period 1, it obtains no rating and earns

$$\frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)} + q^L, \tag{5}$$

which strictly decreases in δ^* for all $\gamma \in (0,1)$ and $q^H > q^L$.

To start we show that $\delta^* = 1$ can only be an equilibrium if no mixed-strategy equilibrium exists. Suppose $\delta^* = 1$. Then (4) and (5) become $\kappa q^L - \frac{e}{\Delta} + q^H$ and $\gamma q^H + (1-\gamma)q^L + q^L$, respectively. For $\delta^* = 1$ to be optimal, it must be the case that

$$\kappa q^L - \frac{e}{\Delta} + q^H \leq \gamma q^H + (1-\gamma)q^L + q^L. \tag{6}$$

Since (4) strictly increases in δ^* and (5) strictly decreases in δ^*, this means whenever $\delta^* = 1$ is an equilibrium, we cannot have a mixed-strategy equilibrium. We conclude that $\delta^* = 1$

can only be an equilibrium if no mixed-strategy equilibrium exists.

We now show that $\delta^* = 0$ cannot be an equilibrium. Suppose towards a contradiction that $\delta^* = 0$. Then (4) and (5) become $\kappa q^L - \frac{e}{\Delta} + \gamma q^H + (1-\gamma)q^L$ and $q^H + q^L$, respectively. But since $q^H > q^H + (1-\gamma)q^L$ and $q^L > \kappa q^L - \frac{e}{\Delta}$, low-quality firms optimally set $\overline{p} = q^H$ when consumers believe they set this price with probability zero in period 1, a contradiction. We conclude that $\delta^* = 0$ cannot be an equilibrium.

We now characterize the mixed-strategy equilibrium. To have a mixed-strategy equilibrium, consumers must have beliefs such that (4) = (5) and low-quality firms must play some δ^* such that these beliefs are correct. Thus, in a mixed-strategy equilibrium, we have

$$\kappa q^L - \frac{e}{\Delta} + \frac{\gamma q^H + (1-\delta^*)(1-\gamma)q^L}{\gamma + (1-\delta^*)(1-\gamma)} = \frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)} + q^L. \tag{7}$$

We have two candidates that solve this equation:

$$\delta^* = \frac{1}{2} - \frac{\gamma(q^H - q^L)}{(1-\gamma)(q^L(1-\kappa) + \frac{e}{\Delta})} \pm \frac{(4\gamma^2(q^H - q^L)^2 + (1+\gamma)^2(q^L(1-\kappa) + \frac{e}{\Delta})^2)^{\frac{1}{2}}}{2(1-\gamma)(q^L(1-\kappa) + \frac{e}{\Delta})}$$

Recall that as a probability, δ^* is bound by 0 and 1.

Consider the scenario where the last term is subtracted.

$$\begin{aligned}
&\frac{1}{2} - \frac{\gamma(q^H - q^L)}{(1-\gamma)(q^L(1-\kappa) + \frac{e}{\Delta})} - \frac{(4\gamma^2(q^H - q^L)^2 + (1+\gamma)^2(q^L(1-\kappa) + \frac{e}{\Delta})^2)^{\frac{1}{2}}}{2(1-\gamma)(q^L(1-\kappa) + \frac{e}{\Delta})} \\
&< \frac{1}{2} - \frac{\gamma(q^H - q^L)}{(1-\gamma)(q^L(1-\kappa) + \frac{e}{\Delta})} - \frac{((1+\gamma)^2(q^L(1-\kappa) + \frac{e}{\Delta})^2)^{\frac{1}{2}}}{2(1-\gamma)(q^L(1-\kappa) + \frac{e}{\Delta})} \\
&< \frac{1}{2} - \frac{\gamma(q^H - q^L)}{(1-\gamma)(q^L(1-\kappa) + \frac{e}{\Delta})} - \frac{(1+\gamma)}{2(1-\gamma)} \\
&< \frac{1}{2} - \frac{\gamma(q^H - q^L)}{(1-\gamma)(q^L(1-\kappa) + \frac{e}{\Delta})} - \frac{(1-\gamma)}{2(1-\gamma)} = -\frac{\gamma(q^H - q^L)}{(1-\gamma)(q^L(1-\kappa) + \frac{e}{\Delta})} < 0
\end{aligned}$$

. Therefore, we conclude that

$$\delta^* = \frac{1}{2} - \frac{\gamma(q^H - q^L)}{(1-\gamma)(q^L(1-\kappa) + \frac{e}{\Delta})} + \frac{(4\gamma^2(q^H - q^L)^2 + (1+\gamma)^2(q^L(1-\kappa) + \frac{e}{\Delta})^2)^{\frac{1}{2}}}{2(1-\gamma)(q^L(1-\kappa) + \frac{e}{\Delta})}.$$

Further, notice that the optimal δ^* is lies strictly between $\frac{1}{2}$ and 1.

We see from (4) and (5) that $\delta^* < 1$ if $\kappa q^L - \frac{e}{\Delta} + q^H > \gamma q^H + (1-\gamma) q^L + q^L$. Also note that

$$\delta^* > \frac{1}{2} - \frac{\gamma(q^H - q^L)}{(1-\gamma)(q^L(1-\kappa) + \frac{e}{\Delta})} + \frac{(4\gamma^2(q^H - q^L)^2)^{\frac{1}{2}}}{2(1-\gamma)(q^L(1-\kappa) + \frac{e}{\Delta})} = \frac{1}{2}.$$

We now show the equilibrium is unique up to off-equilibrium-path beliefs. This follows immediately from having shown that we cannot have $\delta^* = 0$, and that $\delta^* = 1$ can only be an equilibrium if no mixed-strategy equilibrium exists. Additionally, if a $\delta^* \in (0,1)$ exists such that (7) holds, it must be unique, because (4) strictly increases, and (5) strictly decreases in δ^*. We conclude that if mixed-strategy equlibria exists, it is a unique mixed-strategy, $\delta^* \in (0,1)$ Thus, we either have a unique pure-strategy equilibrium or a unique mixed-strategy equilibrium, but not both. We conclude that the equilibrium is unique up to off-equilibrium-path beliefs.

Therefore, we can conclude that $\delta^* < 1$ if

$$(1-\gamma)(q^H - q^L) > q^L(1-\kappa) + \frac{e}{\Delta}. \tag{8}$$

And this equilibrium is a unique interior solution where $\delta^* \in (\frac{1}{2}, 1)$ up to off-equilibrium-path beliefs. Otherwise, there is a unique corner solution at $\delta^* = 1$ up to off-equilibrium-path beliefs.

$$\delta^* = \begin{cases} \frac{1}{2} - \frac{\gamma(q^H - q^L)}{(1-\gamma)(q^L(1-\kappa) + \frac{e}{\Delta})} + \frac{(4\gamma^2(q^H - q^L)^2 + (1+\gamma)^2(q^L(1-\kappa) + \frac{e}{\Delta})^2)^{\frac{1}{2}}}{2(1-\gamma)(q^L(1-\kappa) + \frac{e}{\Delta})} & \text{if (8) holds} \\ 1 & \text{otherwise} \end{cases} \tag{9}$$

We now show that these equilibria exist.

To start, consider the case where (6) holds. In the candidate equilibrium in period 1, the high-quality firm sets $\overline{p} = \gamma q^H + (1-\gamma) q^L$ with probability 1 and obtains a rating, and the low-quality firm charges $\overline{p}$ with probability 1 and gets no rating. In period 2, the high-quality firm charges a price equal q^H, and the low-quality firm charges q^L. Consumers' beliefs are as follows. In period 1, they believe

$$E[q_1|p_1] = \begin{cases} \gamma q^H + (1-\gamma) q^L & \text{if } p_1 > \kappa q^L - \frac{e}{\Delta} \\ q^L & \text{if } p_1 \leq \kappa q^L - \frac{e}{\Delta}, \end{cases}$$

in the second period, beliefs are independent of prices and are

$$E[q_2|R_1] = \begin{cases} q^H & \text{if } R_1 = 1 \\ q^L & \text{if } R_1 = 0. \end{cases}$$

These beliefs follow Bayes rule on the path of play. The candidate equilibrium is also consistent with our restrictions. Because high-quality firms obtain a rating with probability 1, the candidate equilibrium is consistent with Restriction 1. Because consumers have the same beliefs for all second period prices, and the same beliefs for all first period prices where the low-quality firm obtains no rating, the candidate equilibrium is consistent with Restriction 2.

We now show that firms have no profitable deviations.

In the candidate equilibrium, the high-quality firm earns $\gamma q^H + (1-\gamma)q^L + q^H$. Deviations in period 2 to a higher price would induce zero demand, and deviations to lower prices would reduce margins without increasing demand. There are no profitable deviations in period 2. In period 1, deviations to a higher price reduces demand to zero and earns a maximal total profit of $0 + q^L$. Deviations to a lower price in period 1 reduce margins without increasing demand or increasing ratings. Therefore, there is no profitable deviation in period 1. We conclude that high-quality firms have no profitable deviations.

We now show that low-quality firms have no profitable deviations. In the candidate equilibrium they earn $\gamma q^H + (1-\gamma)q^L + q^L$. Deviations in period 2 to a higher price would induce zero demand, and deviations to lower prices would reduce margins without increasing demand. There are no profitable deviations in period 2. In period 1, deviations to a higher price reduces demand to zero and earns a maximal total profit of $0 + q^L$, which is not a profitable deviation. In period 1, deviations to a lower price above $\kappa q^L - \frac{e}{\Delta}$ does not improve the rating and only reduces margins without raising demand, this is not a profitable deviation. Deviations to lower prices below $\kappa q^L - \frac{e}{\Delta}$ leads to profits weakly below $\kappa q^L - \frac{e}{\Delta} + q^H$, which is not a profitable deviation since (6) holds.

We conclude that if (6) holds, no profitable deviations exist for either type of firm.

Finally, we have shown above that $\overline{p} = E[q_1|\overline{p}]$, which requires $\gamma q^H + (1-\gamma)q^L \leq \kappa q^H - \frac{e}{\Delta}$.

We conclude that if $(1-\gamma)(q^H - q^L) \leq q^L(1-\kappa) + \frac{e}{\Delta}$ and $\gamma q^H + (1-\gamma)q^L \leq \kappa q^H - \frac{e}{\Delta}$, the candidate equilibrium exists. As we have shown above, it must be the unique equilibrium up to off-equilibrium beliefs.

Now consider the case where (8) holds. We have shown above that no pure-strategy equilibrium exists in this case. In the candidate equilibrium in period 1, the high-quality firm sets $\overline{p} = \frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)}$ with probability 1 and obtains a rating. The low-quality firm charges $\overline{p}$ with probability δ^* and gets no rating, and sets $\underline{p} = \kappa q^L - \frac{e}{\Delta}$ with probability $1-\delta^*$ and gets a rating. In period 2, all firms with a good rating charge $\frac{\gamma q^H + (1-\delta^*)(1-\gamma)q^L}{\gamma + (1-\delta^*)(1-\gamma)}$, and firms without a rating charge q^L. Consumers' beliefs are as follows. In period 1, they believe

$$E[q_1|p_1] = \begin{cases} \frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)} & \text{if } p_1 > \kappa q^L - \frac{e}{\Delta} \\ q^L & \text{if } p_1 \leq \kappa q^L - \frac{e}{\Delta}. \end{cases}$$

in the second period, beliefs are independent of prices and are

$$E[q_2|R_1] = \begin{cases} \frac{\gamma q^H + (1-\delta^*)(1-\gamma)q^L}{\gamma + (1-\delta^*)(1-\gamma)} & \text{if } R_1 = 1 \\ q^L & \text{if } R_1 = 0. \end{cases}$$

These beliefs follow Bayes rule on the path of play. The candidate equilibrium is also consistent with our restrictions. Because high-quality firms obtain a rating with probability 1, the candidate equilibrium is consistent with Restriction 1. Because second period beliefs are independent of prices, and consumers have the same beliefs for all first period prices where the low-quality firm obtains no rating, the candidate equilibrium is consistent with Restriction 2.

We now show that firms have no profitable deviations.

We start with low-quality firms, who earn total profits $\kappa q^L - \frac{e}{\Delta} + \frac{\gamma q^H + (1-\delta^*)(1-\gamma)q^L}{\gamma + (1-\delta^*)(1-\gamma)}$. The firm is indifferent between charging $\overline{p}$ and $\underline{p}$, where $\overline{p} > \underline{p}$. If the firm deviates to a price above $\overline{p}$, demand drops to zero and total profits are weakly below $0 + q^L$, this is not a profitable deviation. Deviations to a price $p_1 \in (\underline{p}, \overline{p})$, for which the firm gets the same rating as charging $\overline{p}$ and therefore earns the same profit in period 2, but the firm earns a lower margin than when it charges $\overline{p}$ without increasing demand in period 1, this is not a profitable deviation. Deviations to a price below $\underline{p}$ lead to the same rating as when charging $\underline{p}$ and therefore the same continuation profits, but decrease margins in period 1 without increasing demand, this is not a profitable deviation. In period 2, the low-quality firm extracts expected total surplus conditional on the rating, and cannot strictly increase profits. We conclude that low-quality firms have no profitable deviation.

We now show that high-quality firms have no profitable deviation. In the candidate equilibrium, high-quality firms earn $\frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)} + \frac{\gamma q^H + (1-\delta^*)(1-\gamma)q^L}{\gamma + (1-\delta^*)(1-\gamma)}$. In the second period, high.quality firms extract total surplus conditional on their good rating and therefore cannot profitably deviate. In the first period, a higher price reduces demand to zero and earns profits weakly below $0 + q^L$, which is not a profitable deviation. Deviating to a lower price does not improve the rating and therefore does not increase continuation profits, but reduces margins in period 1 without increasing demand, this is also not a profitable deviation. We conclude that high-quality firms have no profitable deviation.

We conclude that no firm has a profitable deviation.

Finally, we need to check $\overline{p} = \min\{\kappa q^H - \frac{e}{\Delta}, E[q_1|\overline{p}]\} = E[q_1|\overline{p}]$, which requires $\frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)} \leq \kappa q^H - \frac{e}{\Delta}$.

We conclude that if $(1-\gamma)(q^H - q^L) > q^L(1-\kappa) + \frac{e}{\Delta}$ and $\frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)} \leq \kappa q^H - \frac{e}{\Delta}$, the candidate equilibrium exists. As we have shown above, it must be the unique equilibrium up to off-equilibrium beliefs.

This concludes the proof. □

Proof of Proposition 2

Proof of Proposition 2.
In this proof, we show that $\frac{\partial \delta^*}{\partial \Delta} < 0$ if $(1-\gamma)(q^H - q^L) - (1-\kappa)q^L > \frac{e}{\Delta}$ and argue it is 0 otherwise.

We know from Proposition 1 that $\delta^* = \frac{1}{2} - \frac{\gamma(q^H - q^L)}{(1-\gamma)(q^L(1-\kappa) + \frac{e}{\Delta})} + \frac{(4\gamma^2(q^H-q^L)^2 + (1+\gamma)^2(q^L(1-\kappa)+\frac{e}{\Delta})^2)^{\frac{1}{2}}}{2(1-\gamma)(q^L(1-\kappa)+\frac{e}{\Delta})}$, and that $\delta^* \in (\frac{1}{2}, 1)$ when $(1-\gamma)(q^H - q^L) - (1-\kappa)q^L > \frac{e}{\Delta}$. We can then calculate the derivative with respect to Δ, which leads to:

$$\frac{\partial \delta^*}{\partial \Delta} = \frac{e}{\Delta^2} \frac{\gamma(q^H - q^L)[2\gamma(q^H - q^L) - ((2\gamma(q^H - q^L))^2 + ((1+\gamma)(q^L(1-\kappa) + \frac{e}{\Delta}))^2)^{\frac{1}{2}}]}{(1-\gamma)(q^L(1-\kappa) + \frac{e}{\Delta})^2((2\gamma(q^H - q^L))^2 + ((1+\gamma)(q^L(1-\kappa) + \frac{e}{\Delta}))^2)^{\frac{1}{2}}} < 0$$

When $(1-\gamma)(q^H - q^L) - (1-\kappa)q^L \leq \frac{e}{\Delta}$, $\delta^* = 1$, and further increases to Δ cannot increase δ^* as it is is a probability and is weakly bound by 0 and 1.

Thus we have shown that when low-quality firms would play a mixed-strategy, as consumers kindness increases, low-quality firms are more likely to participate in ratings harvesting. Otherwise, low-quality firms play a pure strategy of price mimicking.

This concludes the proof. □

Proof of Corollary 1

Proof of Corollary 1.
In this proof, we show that $\frac{\partial \delta^*}{\partial e} > 0$ if $(1-\gamma)(q^H - q^L) - (1-\kappa)q^L > \frac{e}{\Delta}$ holds.

We know from Proposition 1 that $\delta^* = \frac{1}{2} - \frac{\gamma(q^H - q^L)}{(1-\gamma)(q^L(1-\kappa)+\frac{e}{\Delta})} + \frac{(4\gamma^2(q^H-q^L)^2+(1+\gamma)^2(q^L(1-\kappa)+\frac{e}{\Delta})^2)^{\frac{1}{2}}}{2(1-\gamma)(q^L(1-\kappa)+\frac{e}{\Delta})}$, and that $\delta^* \in (\frac{1}{2}, 1)$ when $(1-\gamma)(q^H - q^L) - (1-\kappa)q^L > \frac{e}{\Delta}$. We can then calculate the derivative with respect to e, which leads to:

$$\frac{\partial \delta^*}{\partial e} = \frac{\gamma(q^H - q^L)(((2\gamma(q^H - q^L))^2 + ((1+\gamma)(q^L(1-\kappa)+\frac{e}{\Delta}))^2)^{\frac{1}{2}} - 2\gamma(q^H - q^L))}{\Delta(1-\gamma)(q^L(1-\kappa)+\frac{e}{\Delta})^2((2\gamma(q^H - q^L))^2 + ((1+\gamma)(q^L(1-\kappa)+\frac{e}{\Delta}))^2)^{\frac{1}{2}}} > 0$$

Thus we have shown that when low-quality firms would play a mixed-strategy, as the opportunity cost of rating increases, low-quality firms are less likely to participate in ratings harvesting.

This concludes the proof. □

Proof of Proposition 3

Proof of Proposition 3.
We show $\frac{\partial \delta^*}{\partial \gamma} \leq 0$ when γ is sufficiently small and $\frac{\partial \delta^*}{\partial \gamma} > 0$ when γ is sufficiently large. We then characterise this switching point, $\overline{\gamma}$, and show its uniqueness and existence.

To start, note from (7), δ^* is such that low-quality firms are indifferent between charging low prices and high prices,

$$\frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)} + q^L = \kappa q^L - \frac{e}{\Delta} + \frac{\gamma q^H + (1-\delta^*)(1-\gamma)q^L}{\gamma + (1-\delta^*)(1-\gamma)}.$$

Taking the derivative of the right-hand side leads to

$$\frac{\partial RHS}{\partial \gamma} = \frac{(q^H - q^L)((1-\delta^*) + (1-\gamma)\gamma\frac{\partial \delta^*}{\partial \gamma})}{(\gamma + (1-\delta^*)(1-\gamma))^2},$$

and for the left-hand side

$$\frac{\partial LHS}{\partial \gamma} = \frac{(q^H - q^L)(\delta^* - (1-\gamma)\gamma\frac{\partial \delta^*}{\partial \gamma})}{(\gamma + (1-\gamma)\delta^*)^2}.$$

Since both derivatives must be equal in equilibrium, we get

$$\frac{\partial \delta^*}{\partial \gamma} = \frac{(2\delta^* - 1)(\gamma^2 + \delta^{*2}(1-\gamma)^2 - \delta^*(1-\gamma)^2)}{\gamma(1-\gamma)((\gamma + (1-\delta^*)(1-\gamma))^2 + (\gamma + (1-\gamma)\delta^*)^2)} \tag{10}$$

In particular, we show that the sign of $\frac{\partial \delta^*}{\partial \gamma}$ switches at some point $\overline{\gamma}$. Since the denominator is strictly positive, the expression is negative if and only if the numerator is negative, i.e.

$$(2\delta^* - 1)(\gamma^2 - (1-\gamma)^2\delta^*(1-\delta)) < 0.$$

And positive when

$$(2\delta^* - 1)(\gamma^2 - (1-\gamma)^2\delta^*(1-\delta)) > 0,$$

and 0 if

$$(2\delta^* - 1)(\gamma^2 - (1-\gamma)^2\delta^*(1-\delta)) = 0.$$

Since $\delta^* > 0.5$, the when evaluating the sign of $(2\delta^* - 1)(\gamma^2 - (1-\gamma)^2\delta^*(1-\delta))$, we only need consider $(\gamma^2 - (1-\gamma)^2\delta^*(1-\delta))$

We show that there is only one γ such that $(2\delta^* - 1)(\gamma^2 - (1-\gamma)^2\delta^*(1-\delta)) = 0$, therefore there is a unique switching point.

$$\overline{\gamma} = \frac{(q^H - q^L)^2 - (q^L(1-\kappa) + \frac{e}{\Delta})^2}{3(q^H - q^L)^2 + (q^L(1-\kappa) + \frac{e}{\Delta})^2} \tag{11}$$

We show that $\overline{\gamma} \in (0,1)$. The denominator is strictly positive. From (1), the numerator is strictly positive. Hence, $\overline{\gamma} > 0$. Moreover, because the denominator is always strictly larger than the numerator, $\overline{\gamma} < 1$.

Finally, we show that if $\gamma < \overline{\gamma}$, then $\frac{\partial \delta^*}{\partial \gamma} < 0$, and $\frac{\partial \delta^*}{\partial \gamma} > 0$ when $\gamma \in (\overline{\gamma}, 1)$.

Notice that when $\gamma \to 0$, and from (9) $\delta^* \to 1$. Thus $\delta^*(1-\delta^*) \to 0$ and $\frac{\gamma^2}{(1-\gamma)^2} \to 0$. And when $\gamma \to 1$, $\delta^* = 1$. Further, when $\gamma = 1$, $\frac{\gamma^2}{(1-\gamma)^2} = \infty$.

We show that $\delta^*(1-\delta^*) > \frac{\gamma^2}{(1-\gamma)^2}$ when γ is sufficiently small. Consider that $\frac{\gamma^2}{(1-\gamma)^2}$ is strictly convex, with $\frac{\partial \frac{\gamma^2}{(1-\gamma)^2}}{\partial \gamma} = \frac{2\gamma}{(1-\gamma)^3} > 0$ and $\frac{\partial^2 \frac{\gamma^2}{(1-\gamma)^2}}{\partial \gamma^2} = \frac{2+4\gamma}{(1-\gamma)^4} > 0$. Evaluated at $\gamma \to 0$, $\frac{\partial \frac{\gamma^2}{(1-\gamma)^2}}{\partial \gamma} = \frac{2\gamma}{(1-\gamma)^3} \to 0$. Further, consider that $\frac{\partial \delta^*(1-\delta^*)}{\partial \gamma} = \frac{\partial \delta^*}{\partial \gamma}(1-2\delta^*)$. Evaluated at $\gamma \to 0$, $\delta^* \to 1$ and $\frac{\partial \delta^*}{\partial \gamma} < 0$. Then, $\frac{\partial \delta^*(1-\delta^*)}{\partial \gamma} = \frac{\partial \delta^*}{\partial \gamma}(1-2\delta^*) > 0$. Hence, there exists a range of

$\gamma \in (0,1)$ where $\delta^*(1-\delta^*) > \frac{\gamma^2}{(1-\gamma)^2}$ is satisfied. We label the first upper boundary (closest to 0) of this range as γ', such that $\gamma' \in (0,1)$ and when $\gamma \in (0,\gamma')$, $\delta^*(1-\delta^*) > \frac{\gamma^2}{(1-\gamma)^2}$ is satisfied and $\frac{\partial \delta^*}{\partial \gamma} < 0$.

Additionally, when $\gamma \to 1$, $\delta^* \to 1$ and $\frac{\gamma^2}{(1-\gamma)^2} \to \infty$. This implies that $\frac{\gamma^2}{(1-\gamma)^2} > \delta^*(1-\delta^*)$ for some range of γ and $\frac{\partial \delta^*}{\partial \gamma} > 0$. This implies that at $\gamma \to 1$, $\frac{\partial \delta^*(1-\delta^*)}{\partial \gamma} = \frac{\partial \delta^*}{\partial \gamma}(1-2\delta^*) < 0$. Therefore, we can conclude that there exists a range of $\gamma \in (0,1)$ where $\frac{\gamma^2}{(1-\gamma)^2} > \delta^*(1-\delta^*)$ is satisfied. We label the first lower boundary (closest to 1) of this range as γ'', such that $\gamma'' \in (0,1)$ and when $\gamma \in (\gamma'',1)$, $\frac{\gamma^2}{(1-\gamma)^2} > \delta^*(1-\delta^*)$ is satisfied and $\frac{\partial \delta^*}{\partial \gamma} > 0$.

Notice that by definition $\gamma'' \geq \gamma'$. We have shown before that there is a unique switching point, therefore $\overline{\gamma} = \gamma'' = \gamma'$.

We conclude that there is a unique switching point $\overline{\gamma}$, below which $\frac{\partial \delta^*}{\partial \gamma} < 0$, and above which $\frac{\partial \delta^*}{\partial \gamma} > 0$. Where $\frac{\partial \delta^*}{\partial \gamma} = 0$ only if $\gamma = \overline{\gamma}$, and $\overline{\gamma} \in (0,1)$. □

Proof of Proposition 4

Proof of Proposition 4.
In this proof, we show that if a social planner concerned with the welfare of consumers would set an optimal e, e^{cs}.

First, we find consumer surplus. This is the sum of the difference between actual price and quality that consumers receive in each period.

$$\begin{aligned}
CS_1 =& \gamma[q^H - \frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)}] + (1-\delta^*)(1-\gamma)[q^L - \kappa q^L + \frac{e}{\Delta}] + \\
& \delta^*(1-\gamma)[q^L - \frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)}] = (1-\delta^*)(1-\gamma)[q^L - \kappa q^L + \frac{e}{\Delta}] \\
CS_2 =& \gamma[q^H - \frac{\gamma q^H + (1-\delta^*)(1-\gamma)q^L}{\gamma + (1-\delta^*)(1-\gamma)}] + (1-\delta^*)(1-\gamma)[q^L - \frac{\gamma q^H + (1-\delta^*)(1-\gamma)q^L}{\gamma + (1-\delta^*)(1-\gamma)}] + \\
& \delta^*(1-\gamma)[q^L - q^L] = 0.
\end{aligned}$$

Therefore, consumer surplus arises only from the low-quality firm's attempt to receive a good rating, and total consumer surplus in our model is given by

$$CS = (1-\delta^*)(1-\gamma)[q^L - \kappa q^L + \frac{e}{\Delta}]. \tag{12}$$

This is (2). From (2) we can evaluate the effects of changes to effort cost.

First, we show that consumer surplus is concave in e.

$$\frac{\partial CS}{\partial e} = \frac{1}{2}[1-\gamma - \frac{(1+\gamma)^2(q^L(1-\kappa)+\frac{e}{\Delta})}{\sqrt{4\gamma^2(q^H-q^L)^2+(1+\gamma)^2(q^L(1-\kappa)+\frac{e}{\Delta})^2}}]$$

This is positive if and only if

$$(1-\gamma)^2\gamma(q^H-q^L)^2 > (1+\gamma)^2(q^L(1-\kappa)+\frac{e}{\Delta})^2$$

, and $\frac{\partial CS}{\partial e}=0$ with equality. This condition is (3).

We now look at the second derivative.

$$\frac{\partial^2 CS}{\partial e^2} = -\frac{2\gamma^2(1+\gamma)^2(q^H-q^L)^2}{\Delta^2((2\gamma(q^H-q^L))^2+((1+\gamma)(q^L(1-\kappa)+\frac{e}{\Delta}))^2)^{\frac{3}{2}}} < 0$$

Second, we solve for the optimal level of effort required to leave a rating.

$$e = -(1-\kappa)q^L\Delta \pm \frac{\Delta(q^H-q^L)(1-\gamma)\sqrt{\gamma}}{1+\gamma}$$

We may reject the negative as we assume that $e \geq 0$. Therefore,

$$e^{cs} = -(1-\kappa)q^L\Delta + \frac{\Delta(q^H-q^L)(1-\gamma)\sqrt{\gamma}}{1+\gamma}$$

where e^{cs} is the level of effort cost that maximises consumer surplus. This e^{cs} is indeed positive when (3) holds. Which is the restriction required for $\frac{\partial CS}{\partial e} > 0$ at $e = 0$.

When (3) does not hold, then $\frac{\partial CS}{\partial e} < 0$ and this implies that $e^{cs} = 0$, the lower bound.

Therefore, for a planner maximizing the welfare of consumers,
$e^{cs} = -(1-\kappa)q^L\Delta + \frac{\Delta(q^H-q^L)(1-\gamma)\sqrt{\gamma}}{1+\gamma}$ when (3) holds, and 0 otherwise.

This concludes the proof. □

Proof of Corollary 2

Proof of Corollary 2.
In this proof, we show that in expectation, sellers prefer $e = 0$, and thus completely uninformative ratings. Because high-quality firms prefer more-informative ratings, we argue that the expected sellers' preference for uninformative ratings is driven by low-quality firms.

First, we look at the average profit function of the firm,

$$\begin{aligned}
\pi = &\gamma[\frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)} + \frac{\gamma q^H + (1-\delta^*)(1-\gamma)q^L}{\gamma + (1-\delta^*)(1-\gamma)}] + \\
&(1-\gamma)[(1-\delta^*)[\kappa q^L - \frac{e}{\Delta} + \frac{\gamma q^H + (1-\delta^*)(1-\gamma)q^L}{\gamma + (1-\delta^*)(1-\gamma)}] + \delta^*[\frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)} + q^L]] \\
&= 2[\gamma q^H + (1-\gamma)q^L] - (1-\delta^*)(q^L(1-\kappa) + \frac{e}{\Delta})
\end{aligned}$$

Taking the derivative to e,

$$\begin{aligned}
\frac{\partial \pi}{\partial e} &= \frac{\partial \delta^*}{\partial e}[(1-\kappa)q^L + \frac{e}{\Delta}] - \frac{(1-\gamma)(1-\delta^*)}{\Delta} \\
&= -\frac{1}{2} + \frac{(1+\gamma)^2(q^L(1-\kappa) + \frac{e}{\Delta})}{2(1-\gamma)\sqrt{4\gamma^2(q^H - q^L)^2 + (1+\gamma)^2(q^L(1-\kappa) + \frac{e}{\Delta})^2}}
\end{aligned}$$

and this is negative when (3) holds.

Therefore, on average firms prefer the smallest level of e, and the level of effort cost that maximises firm's profit is $e^s = 0$.

Second, we show that high-quality firms prefer informative ratings.

$$\begin{aligned}
\pi^H &= \frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)} + \frac{\gamma q^H + (1-\delta^*)(1-\gamma)q^L}{\gamma + (1-\delta^*)(1-\gamma)} \\
\frac{\partial \pi^H}{\partial e} &= -\frac{(1-\gamma)^2\gamma(1+\gamma)(q^H - q^L)(1-2\delta^*)\frac{\partial \delta^*}{\partial e}}{(\gamma + (1-\gamma)(1-\delta^*))^2(\gamma + (1-\gamma)\delta^*)^2}
\end{aligned}$$

Recall that $\delta^* \in (\frac{1}{2}, 1)$, and $\frac{\partial \delta^*}{\partial e} > 0$ when (1) holds. Therefore, $\frac{\partial \pi^H}{\partial e} > 0$.

This means that when low-quality firms would play a mixed-strategy, more-informative ratings benefits high-quality firms.

We can show that (3) is a stricter condition than (1).

From (3),

$$\begin{aligned}
(1-\gamma)^2\gamma(q^H - q^L)^2 &\geq (1+\gamma)^2(q^L(1-\kappa) + \frac{e}{\Delta})^2 \\
\frac{\gamma}{(1+\gamma)^2} &\geq \frac{(q^L(1-\kappa) + \frac{e}{\Delta})^2}{(1-\gamma)^2(q^H - q^L)^2}
\end{aligned}$$

And from (1),

$$
\begin{aligned}
(1-\gamma)(q^H-q^L)-(1-\kappa)q^L &> \frac{e}{\Delta} \\
(1-\gamma)(q^H-q^L) > q^L(1-\kappa)+\frac{e}{\Delta} &\text{ since both sides are positive,} \\
(1-\gamma)^2(q^H-q^L)^2 &> (q^L(1-\kappa)+\frac{e}{\Delta})^2 \\
1 &> \frac{(q^L(1-\kappa)+\frac{e}{\Delta})^2}{(1-\gamma)^2(q^H-q^L)^2}
\end{aligned}
$$

Finally, notice that $\gamma \in (0,1)$ and thus $\frac{\gamma}{(1+\gamma)^2} < 1$. Therefore, (3) is a stricter condition than (1).

We conclude that more-informative ratings leads to an decrease in the average profits of the firm. This decrease in profits is driven by low-quality firms, and high-quality firms benefit from more-informative ratings environments. □

Proof of Proposition 5

Proof of Proposition 5.
We show that there is some γ^{cs} that maximises consumer surplus, and that consumer surplus is concave in γ.

To start, recall from Proposition 4 that total consumer surplus reduces to (2), i.e. $CS = (1-\delta^*)(1-\gamma)[q^L-\kappa q^L+\frac{e}{\Delta}]$. We take the derivative of (2) with respect to γ and show that there is some $\gamma^{cs} < \overline{\gamma}$ that maximises consumer surplus.

$$
\frac{\partial CS}{\partial \gamma} = -(1-\delta^*+(1-\gamma)\frac{\partial \delta^*}{\partial \gamma})(q^L(1-\kappa)+\frac{e}{\Delta}) \tag{13}
$$

Since $q^L(1-\kappa)+\frac{e}{\Delta} > 0$, therefore, the sign of $\frac{\partial CS}{\partial \gamma}$ depends on $-(1-\delta^*+(1-\gamma)\frac{\partial \delta^*}{\partial \gamma})$.

We solve for γ^{cs}, the optimal choice of γ that maximises consumer surplus.

$$
\begin{aligned}
\gamma^{cs} =& \frac{-(q^H-q^L)(q^L(1-\kappa)+\frac{e}{\Delta})^2}{(q^H-q^L)(4(q^H-q^L)^2+(q^L(1-\kappa)+\frac{e}{\Delta})^2)} \pm \\
& \frac{((q^H-q^L)^3(q^L(1-\kappa)+\frac{e}{\Delta})(2(q^H-q^L)-(q^L(1-\kappa)+\frac{e}{\Delta}))^2)^{\frac{1}{2}}}{(q^H-q^L)(4(q^H-q^L)^2+(q^L(1-\kappa)+\frac{e}{\Delta})^2)}
\end{aligned}
$$

Because the denominator is positive, we reject the negative, as $\gamma \in (0,1)$. Therefore, we show that $\gamma^{cs} \in (0,1)$ exists if $(q^H-q^L)(2(q^H-q^L)-(q^L(1-\kappa)+\frac{e}{\Delta}))^2 \geq (q^L(1-\kappa)+\frac{e}{\Delta})^3$.

We now show that $(q^H-q^L)(2(q^H-q^L)-(q^L(1-\kappa)+\frac{e}{\Delta}))^2 \geq (q^L(1-\kappa)+\frac{e}{\Delta})^3$ always holds. By applying $(q^H-q^L) > \gamma q^H + (1-\gamma)q^L - \kappa q^L + \frac{e}{\Delta} > q^L(1-\kappa)+\frac{e}{\Delta}$,

$$\begin{aligned}(q^H-q^L)(2(q^H-q^L)-(q^L(1-\kappa)+\frac{e}{\Delta}))^2 &\geq (q^L(1-\kappa)+\frac{e}{\Delta})^3\\ (q^H-q^L)(q^L(1-\kappa)+\frac{e}{\Delta})^2 &> (q^L(1-\kappa)+\frac{e}{\Delta})^3\\ (q^H-q^L) &> (q^L(1-\kappa)+\frac{e}{\Delta})\end{aligned}$$

This is a weaker condition than (1).

Thus we conclude that γ^{cs} exists when low-quality firms play a mixed-strategy.

We now show that $\frac{\partial CS}{\partial \gamma}$ is strictly concave. First, we shall argue that $\gamma^{cs} < \overline{\gamma}$. Second, we show that when $\gamma > \gamma^{cs}$, $\frac{\partial CS}{\partial \gamma} < 0$. Finally, we show that $\frac{\partial CS}{\partial \gamma} > 0$ when $\gamma < \gamma^{cs}$.

Since $\overline{\gamma}$ solves $\frac{\partial \delta^*}{\partial \gamma}$ implies $\frac{\partial \delta^*}{\partial \gamma} = 0$ at $\overline{\gamma}$. Further, $\delta^* \in (\frac{1}{2}, 1)$ for $\gamma > 0$, implying that $(1-\delta^*) > 0$. Therefore, from (13), at $\overline{\gamma}$, $\frac{\partial CS}{\partial \gamma} < 0$. This implies that $\gamma^{cs} < \overline{\gamma}$.

Second, we show that when $\gamma > \gamma^{cs}$, $\frac{\partial CS}{\partial \gamma} < 0$. When $\gamma > \overline{\gamma}$, we know that $(1-\delta^*) > 0$, $(1-\gamma) > 0$, and from Proposition 3 $\frac{\partial \delta^*}{\partial \gamma} > 0$. This implies that $\frac{\partial CS}{\partial \gamma} < 0$ when $\gamma > \gamma^{CS}$.

Finally, we show that when $\gamma < \gamma^{cs}$, $\frac{\partial CS}{\partial \gamma} > 0$. Notice that $(1-\delta^*+(1-\gamma)\frac{\partial \delta^*}{\partial \gamma}) \to 1-\frac{q^H-q^L}{q^L(1-\kappa)+\frac{e}{\Delta}}$ when evaluated at $\gamma \to 0$. From (1) we know that this is strictly negative. Therefore, $\frac{\partial CS}{\partial \gamma} > 0$ at $\gamma \to 0$. And we have shown that there is only one point where the sign changes when $\gamma > 0$. Therefore, when $\gamma < \gamma^{cs}$, $\frac{\partial CS}{\partial \gamma} > 0$

This concludes the proof and we have shown that there exist some $\gamma^{cs} \in (0, \overline{\gamma})$ that maximises consumer surplus,

$$\begin{aligned}\gamma^{cs} =& \frac{-(q^H-q^L)(q^L(1-\kappa)+\frac{e}{\Delta})^2}{(q^H-q^L)(4(q^H-q^L)^2+(q^L(1-\kappa)+\frac{e}{\Delta})^2)} +\\ & \frac{((q^H-q^L)^3(q^L(1-\kappa)+\frac{e}{\Delta})(2(q^H-q^L)-(q^L(1-\kappa)+\frac{e}{\Delta}))^2)^{\frac{1}{2}}}{(q^H-q^L)(4(q^H-q^L)^2+(q^L(1-\kappa)+\frac{e}{\Delta})^2)}\end{aligned}$$

and consumer surplus is strictly concave in γ.

This concludes the proof. □

Proof of Lemma 1

Proof of Lemma 1.

To show that sellers of all types benefit from quality controls, we look at the lifetime profits of both high- and low-quality firms independently.

We begin with low-quality firms.

$$\pi^L = \delta^*(\frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)} + q^L) + (1-\delta^*)(\kappa q^L - \frac{e}{\Delta} + \frac{\gamma q^H + (1-\delta^*)(1-\gamma)q^L}{\gamma + (1-\delta^*)(1-\gamma)})$$

We know that δ^* is such that the low-quality firm is indifferent between $\frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)} + q^L$ and $\kappa q^L - \frac{e}{\Delta} + \frac{\gamma q^H + (1-\delta^*)(1-\gamma)q^L}{\gamma + (1-\delta^*)(1-\gamma)}$.

Therefore,

$$\begin{aligned}
\pi^L &= \frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)} + q^L \\
\frac{\partial \pi^L}{\partial \gamma} &= \frac{(q^H - q^L)(\delta^* - \gamma(1-\gamma)\frac{\partial \delta^*}{\partial \gamma})}{(\gamma + \delta^*(1-\gamma))^2}
\end{aligned}$$

Since the denominator is positive, and $q^H - q^L > 0$, we evaluate $\delta^* - \gamma(1-\gamma)\frac{\partial \delta^*}{\partial \gamma}$. $\delta^* - \gamma(1-\gamma)\frac{\partial \delta^*}{\partial \gamma} = \frac{(1+\gamma)(q^L(1-\kappa)+\frac{e}{\Delta})}{2\sqrt{4\gamma^2(q^H-q^L)^2+(1+\gamma)^2(q^L(1-\kappa)+\frac{e}{\Delta})^2}} + \frac{1}{2} > 0$ Therefore, profits of low-quality firms benefits from quality controls.

Moreover, we show that high-quality firms also benefit from quality controls.

$$\begin{aligned}
\pi^H =& \frac{\gamma q^H + \delta^*(1-\gamma)q^L}{\gamma + \delta^*(1-\gamma)} + \frac{\gamma q^H + (1-\delta^*)(1-\gamma)q^L}{\gamma + (1-\delta^*)(1-\gamma)} \\
\frac{\partial \pi^H}{\partial \gamma} =& \frac{32\gamma^2(q^H - q^L)^3(q^L(1-\kappa) + \frac{e}{\Delta})^2\sqrt{4\gamma^2(q^H - q^L)^2 + (1+\gamma)^2(q^L(1-\kappa) + \frac{e}{\Delta})^2}}{(\gamma + \delta^*(1-\gamma))^2(\gamma + (1-\delta^*)(1-\gamma))^2} - \\
& \frac{32\gamma^2(q^H - q^L)^3(q^L(1-\kappa) + \frac{e}{\Delta})^2(2\gamma(q^H - q^L))}{(\gamma + \delta^*(1-\gamma))^2(\gamma + (1-\delta^*)(1-\gamma))^2}
\end{aligned}$$

Because $\sqrt{4\gamma^2(q^H - q^L)^2 + (1+\gamma)^2(q^L(1-\kappa) + \frac{e}{\Delta})^2} - 2\gamma(q^H - q^L) > 0$, it is immediate that $\frac{\partial \pi^H}{\partial \gamma} > 0$.

Therefore, both high- and low-quality firms benefit when platforms implements quality controls.

This concludes the proof. $\square$