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# Unaware consumers and disclosure of deficiencies

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# Unaware consumers and disclosure of deficiencies*

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**Abstract**

We analyze firms' incentives to disclose deficiencies of their goods when consumers lack information. We distinguish two types of information: First, only some consumers are *aware* of the existence of deficiencies, which reduce the quality of the goods. Second, only some consumers have the *expertise* to infer the true levels of deficiencies once they are aware of the existence of deficiencies. We show that the interplay of awareness and expertise in a market affects firms' incentives to disclose. In particular, we demonstrate that more awareness and/or expertise in a market does not universally lead to more disclosure but depends on the level of competition in the market. Conversely, increasing competition does not always increase firms' incentives to disclose.

KEYWORDS: Awareness, Competition, Disclosure, Expertise, Product Quality.
JEL CODES: D83, L15.

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# 1 Introduction

As several scandals show, firms often remain silent instead of disclosing deficiencies of their goods. For example, in 2020, many consumers were not aware that a fraction of masks that were labeled as FFP2 failed the quality standard associated with FFP2 masks (see, e.g., Kümpel et al. 2020). Similarly, in several food scandals, unexpected substances, such as weed-killers, were discovered (see, e.g., Nelson 2017) or food safety dates manipulated (see, e.g., Goodley 2017). In addition, firms often remain silent about important quality features of their goods, for example, energy efficiency of washing machines.

One problem in such situations is that consumers are often unaware of possible deficiencies. For example, consumers do not know that a particular weed killer exists and are, therefore, unable to consider the possibility that this weed killer contaminates the product. Furthermore, sometimes consumers are aware that a deficiency could exist, but at the time of the consumption decision this knowledge does not come to mind.[1]

Besides awareness, consumers need a certain level of expertise to understand the true quality of goods. For example, an ordinary consumer will not be able to check goods for a particular weed killer, even if they are aware of the possibility that such a weed killer could contaminates the good. In contrast, an expert, like a chemist, might have the expertise to check the goods for traces of the weed killer. However, in most cases expertise is not dependent on a formal education. Often, consumers gain expertise by investing time to check test reports or to gather information. For example, although being aware of the importance of energy consumption is not sufficient to infer deficiencies in energy efficiency of washing machines, consumers can invest time and effort to browse test reports or to understand the energy efficiency information and thus to observe the true energy efficiency of different washing machines. Similarly, in the case of FFP2 masks, an increasing fraction of consumers has become aware of deficiencies, but has not invested the time to gather information about how to check the quality of masks and thus still lacks the expertise to check the quality of FFP2 masks. In contrast, consumers who have the expertise to check goods for deficiency will not think to do so unless they are made aware of the possibility of deficiencies. Thus, when consumers' lack awareness and/or expertise, to make a fully informed consumption decision, consumers are dependent on the firms disclosing these deficiencies.

Our objective is to analyze the incentives of firms to disclose their deficiencies if consumers lack awareness and expertise regarding these deficiencies. We develop a model of firms' strategic decisions to disclose deficiencies. We assume that only a fraction of consumers considers the possibility of deficiencies; we call these consumers *aware*. The

[1] Experimental and empirical evidence increasingly documents individuals' inattention during decision making (see, e.g., Gabaix 2019, for an overview). For example, Chetty et al. (2009) show that although consumers are aware of the existence of sales taxes they are inattentive to the tax at the time of the purchase.

remaining consumers do not consider the possibility of deficiencies; they are *unaware*. In addition, once consumers are aware, some consumers are able to check the goods for the exact levels of deficiencies, i.e., these consumers are *experts*. The remaining consumers are unable to check the goods for the exact levels of deficiencies and have to build expectations, i.e., these consumers are *amateurs*. This distinction of consumers allows us to analyze the disclosing decision of firms in different markets. A firm can affect the distribution of aware and expert consumers in the market with its disclosure decision: If a firm discloses its deficiency, all consumers become aware that deficiencies exist. In addition, all consumers observe the true deficiency of the disclosing firm perfectly, i.e., all consumers become experts about the disclosing firm's deficiency.

Our analysis consists of two parts. First, we analyze the disclosure decision of two firms when deficiencies are drawn by nature. This case captures the short term where firms cannot influence their level of deficiency. We show that awareness and expertise play a central role in determining market transparency, i.e., whether firms disclose. We show that the existence of an equilibrium, where both firms remain silent regarding their deficiencies, hinges on the fraction of aware and expert consumers. In particular, we demonstrate that increasing awareness and/or expertise in a market does not necessarily lead to more disclosure by the firms. Two effects motivate a firm to disclose. First, firms have a higher incentive to disclose, if consumers on average gain a more favorable impression of the disclosing firm's good. Second, firms have a higher incentive to disclose, if consumers on average gain a less favorable impression of the rival's good. Whether the average effect is beneficial depends on the awareness and expertise in the market. In addition, we highlight the role of competition and show that increasing competition does not necessarily lead to more market transparency.

Second, we extend the model to allow firms to invest in quality. This case captures the long term where firms have sufficient time to adjust their investments to reduce deficiencies. We show that investments in quality and the probability of disclosure increase with the fraction of aware and expert consumers. In addition, we find that, for a small fraction of aware consumers, the investment in quality and the probability to disclose is higher, the more intense the competition in a market: If most consumers are unaware of the existence of deficiencies, a monopolist has no incentive to invest to reduce deficiencies that consumers do not take into account. In contrast, duopolists have some incentive to invest to reduce their deficiencies, because this allows them to distinguish themselves from their competitor and thus increase their profits. Yet, for a large fraction of aware consumers, the investment in quality and the probability to disclose is lower the more intense the competition in the market: If most consumers are aware of the existence of deficiencies, a monopolist has an incentive to invest in the reduction of deficiencies, because goods without deficiencies allow him to charge higher prices. In contrast, duopolists cannot fully extract these higher prices, because the competition decreases the prices. As a result, competition can reduce an individual firm's incentive to invest in quality and to disclose its deficiency.

These results show that firms do not always voluntarily disclose deficiencies of their goods. This leaves room for interventions by a market authority to raise transparency, i.e., to increase disclosure. We discuss the effects of information campaigns, facilitating competition, and the implementation of a minimum standard. We show that neither information campaigns nor minimum standards always induce firms to disclose. Whether information campaigns or minimum standards affect firms' disclosure decisions depends on the market's characteristics such as the level of competition. Similarly, facilitating competition need not have the intended effect of increasing transparency: Only if consumers' are sufficiently unaware (relative to their level of expertise) does facilitating competition induce firms to disclose more. Thus, our results highlight the importance to distinguish between information that raises awareness and information that raises expertise. In addition, our results call attention to the importance of the underlying market characteristics to assess the success of such public policies.

The remainder of the article is structured as follows. Section 2 discusses our contributions to the related literature. Section 3 introduces the model. In Section 4, we derive the market equilibria when deficiencies are exogenously given. In Section 5, we extend the model to analyze investments in quality and the probability to disclose. In Section 6 we discuss different policy measures and their influence on market transparency. Section 7 concludes.

## 2 Related literature

In his seminal article, Akerlof (1970) shows that asymmetric quality information between buyers and sellers can lead to adverse selection. However, adverse selection vanishes if firms can credibly and truthfully disclose quality information (Grossman & Hart 1980, Grossman 1981, Milgrom 1981, Milgrom & Roberts 1986, Okuno-Fujiwara et al. 1990): When firms remain silent, consumers cannot distinguish between high- and low-quality goods. Consequently, firms with above-average quality have an incentive to disclose their quality to distinguish themselves from their competitors which allows them to charge higher prices. Step by step, the market *unravels* until every firm (except the firm with the lowest quality) discloses its quality.

However, empirical and experimental evidence documents instances where this unraveling result breaks down (see, e.g., Mathios 2000, Jin 2005, Bederson et al. 2018). Models account for the breakdown of the unraveling result, for example, if disclosure is costly (Viscusi 1978, Jovanovic 1982, Jansen 2017), if consumers' tastes for quality and a horizontal characteristic of the good are correlated (Hotz & Xiao 2013), if firms have reputational concerns (Grubb 2011), if mandatory disclosure rules induce firms to acquire less information in the first place (Matthews & Postlewaite 1985, Shavell 1994, Polinsky & Shavell 2012), or for product-use information (Bar-Gill & Board 2012). For an excellent survey see Dranove & Jin (2010).

Most articles that document a breakdown of the unraveling result focus on supply side reasons. Yet, the unraveling result hinges especially on the assumption that consumers are skeptical, i.e., that consumers assume the worst of a product whenever a firm remains silent. Ample evidence contests this assumption of fully rational and skeptical consumers (see, e.g., Brown et al. 2012, Szembrot 2018, Jin et al. 2021*a*,*b*). Evidence also accumulates that consumers neglect the existence of certain pieces of information (see, e.g., Chetty et al. 2009, Hanna et al. 2014).[2] As a consequence, we assume that not all consumers are aware of the existence of deficiencies, that some consumers who are aware are incapable of inferring the true deficiency, and that consumers are not skeptical of non-disclosure.

Thus, we first and foremost contribute to the disclosure literature with behavioral consumers. In this strand of the literature, disclosure has been shown to depend, for example, on the fraction of consumers who understand the disclosed information (Fishman & Hagerty 2003), on the fraction of consumers who are attentive to disclosed information and on the costs for searching for overlooked information (Ghosh & Galbreth 2013), on the extent to which consumers are skeptical about undisclosed information (Milgrom & Roberts 1986, Ispano & Schwardmann 2021), and on consumers' loss aversion (Zhang & Li 2021).[3] Hirshleifer et al. (2004) analyze a game where some players are inattentive to the disclosed information and some are not skeptical. However, in contrast to our model, all players are aware of the existence of the information. Hirshleifer et al. (2004) find that the unraveling result fails with limited attentive players. Li et al. (2014) focus on a duopoly where consumers are unaware of some characteristic of the goods and disclosure by one firm implies that all consumers become aware of the existence of that characteristic and the true level of that characteristic. Li et al. (2014) find full unraveling in fully covered markets. Li et al. (2016) analyze a model where only some consumers are aware of a potential deficiency, but no consumer initially knows the true deficiency level. Li et al. (2016) focuses on a monopoly where the firm can advertise to inform some consumers about the true level of deficiency. They show that a monopolist prefers to target advertising to aware consumers and that a larger fraction of aware consumers leads to more disclosure.

We contribute to this literature by extending the composition of the consumer side. We distinguish between aware and unaware consumers as well as expert and amateur consumers. We show that the interplay of the fraction of aware consumers and the fraction of expert consumers affects firms' disclosure decisions and the incentives of firms to invest

[2] See Gabaix (2019) for an excellent overview of limited attention.

[3] The disclosure literature is closely related to the literature on shrouding of add-ons (see, e.g., Gabaix & Laibson 2006, Wenzel 2014, Heidhues et al. 2017).

in reducing deficiencies. By distinguishing between awareness and expertise, we provide a better understanding of the incentives that drive firms to disclose and on the conditions that determine the effectiveness of public policies. In addition, to capture the empirical and experimental evidence about imperfect skepticism and rationality (see, e.g., Brown et al. 2012, Szembrot 2018, Jin et al. 2021*a*,*b*), we focus only on consumers who are not Bayesian updating.

Furthermore, we contribute to the debate whether more competition incentivizes or hampers disclosure. Stivers (2004), for example, finds positive effects of competition on disclosure, whereas, Cheong & Kim (2004), Board (2009), Guo & Zhao (2009), Levin et al. (2009), and Carlin et al. (2012) find negative effects of competition on disclosure. In contrast, we show that the effects of competition on disclosure depend on the awareness and expertise of consumers.

# 3 Model

Consider a market where two firms, firm 1 and firm 2, compete for a unit mass of consumers. Firms produce goods with identical baseline quality $v$. However, the good of each firm $i \in \{1,2\}$ may exhibit a deficiency $d_i \in [0,1]$. If the good of firm $i$ exhibits a deficiency $d_i$, the quality of the good reduces to $v - d_i$. Alternatively, this setup can be interpreted as a situation where with probability $\rho_i$ the deficiency does not occur, i.e., the deficiency is 0, and with the remaining probability $1-\rho_i$ the deficiency does occur, i.e., the deficiency is 1. We assume identical marginal costs that we set to 0.

We assume the following linear-quadratic utility function for all consumers (Singh & Vives 1984):

$$U(x_1,x_2) = (v-d_1)x_1 + (v-d_2)x_2 - \frac{1}{2}(x_1^2 + 2\gamma x_1 x_2 + x_2^2) - p_1 x_1 - p_2 x_2, \qquad (1)$$

where $x_i$ is the quantity which consumers buy from firm $i \in \{1,2\}$ at price $p_i$. The parameter $\gamma \in [0,1]$ captures the substitutability between good 1 and good 2. If $\gamma = 0$, the goods are unrelated and both firms operate as monopolists; if $\gamma = 1$, the goods are perfect substitutes. We focus on the situation where firms sell to all consumers. Therefore, we assume $v > 2/(1-\gamma)$.

We assume that not all consumers observe the deficiencies $d_1$ and $d_2$ perfectly or are even aware that goods can exhibits deficiencies. First, some consumers may be *aware* of the existence of deficiencies, while others are *unaware*. Others are not even aware of the existence of such deficiencies. We denote the fraction of aware consumers by $\alpha \in (0,1)$.

Second, only a fraction of consumers has the expertise to understand the true extent of the deficiency, i.e., these consumers are *experts*. In contrast, *amateurs* cannot observe the deficiencies of a good and thus can only build expectations $E[d] \in (0,1)$. We assume that amateurs are not necessarily skeptical of non-disclosure and do not update their beliefs according to Bayesian rule.[4] Yet, our model would capture extreme skepticism if $E[d] = 1$. Nevertheless, if experts or amateurs are unaware, they completely disregard the deficiency. We denote the fraction of experts by $\chi \in (0, 1)$.

Consequently, dependent on their awareness and expertise, consumers differ with respect to their perception of $d_i$. We denote the perceived deficiency by $\hat{d}_i$. We distinguish four groups of consumers (see Table 1): A fraction $\alpha\chi$ of consumers are experts who are aware of deficiencies. These consumers observe the deficiencies perfectly, i.e., $\hat{d}_i = d_i$. A fraction $\alpha(1-\chi)$ are amateurs who are aware of deficiencies. These consumers know that the goods can exhibit deficiencies, but lack the expertise to check the goods for their true level of deficiency. Thus, these consumers build expectations, i.e., $\hat{d}_i = E[d_i]$. A fraction $(1-\alpha)\chi$ are unaware experts, who are capable of checking the exact level of deficiency but do not know that deficiencies exist. A fraction $(1-\alpha)(1-\chi)$ are unaware amateurs who are both incapable of checking the level of deficiency and unaware of the existence of deficiencies. As long as unaware consumers stay uninformed about the existence of deficiencies, unaware experts and unaware amateurs behave exactly the same. Therefore, all unaware consumers perceive $\hat{d}_i = 0$.

| | $\chi$<br>experts | $1-\chi$<br>amateurs |
|---|---|---|
| $\alpha$ aware | $\hat{d}_i = d_i$ | $\hat{d}_i = E[d]$ |
| $1-\alpha$ unaware | $\hat{d}_i = 0$ | $\hat{d}_i = 0$ |

Table 1: Overview of consumers types and their perceived deficiencies $\hat{d}_i$.

Although, the *experienced* utility given in Equation (1) is the same for all consumers, consumers differ with respect to their *perceived* utility. In the perceived utility, consumers use their perceived deficiencies, $\hat{d}_1$ and $\hat{d}_2$, instead of the the true deficiencies $d_1$ and $d_2$:

$$\hat{U}(x_1, x_2) = (v - \hat{d}_1)x_1 + (v - \hat{d}_2)x_2 - \frac{1}{2}(x_1^2 + 2\gamma x_1 x_2 + x_2^2) - p_1 x_1 - p_2 x_2. \qquad (2)$$

A consumer's demand for the goods is given by maximizing the perceived utility. There-

[4]Bayesian updating and the assumption of extreme skepticism play an important role in the literature (see, e.g., Grossman & Hart 1980, Grossman 1981, Milgrom 1981, Okuno-Fujiwara et al. 1990). Yet, empirical and experimental evidence documents that individuals deviate from Bayesian updating in many situations (see, e.g., Brown et al. 2012, Szembrot 2018, Jin et al. 2021*a*,*b*). In this paper, our focus lies on such consumers who do not use Bayesian updating and who are not necessarily skeptical.

fore, the demand of a consumer is:[5]

$$x_i(p_i, p_j) = \frac{v(1-\gamma) - \hat{d}_i - p_i + \gamma(\hat{d}_j + p_j)}{1-\gamma^2}.$$

As consumers differ in their perception of deficiencies, consumers differ in their maximum willingness to pay and, consequently, in their demand. Thus, the total demand for the good of a firm depends on the composition of the consumer side. Firms are perfectly aware of the composition of the consumer side, but do not observe to which specific fraction individual consumers belong.

Figure 1 illustrates the timing of our model. We assume that firms' deficiencies are drawn by Nature and that firms observe the deficiency of their competitor perfectly. Then, firms play a two-stage game: In the first stage, firms decide whether to disclose the deficiencies of their goods or remain silent. We do not assume any costs for disclosure. By disclosing, a firm influences $\alpha$ and $\chi$. If a firm discloses its deficiency, all consumers become aware that deficiencies can exist, i.e., $\alpha = 1$. This shift in awareness $\alpha$ implies that the disclosing firm inflicts an externality on its competitor. In addition, all consumers become experts about the deficiency of the disclosing firm. Thus, if firm $i$ discloses: $\hat{d}_i = d_i$ for all consumers. In the second stage, after observing the disclosure decision of their competitor, firms choose prices. Afterwards, consumers make their consumption decision.

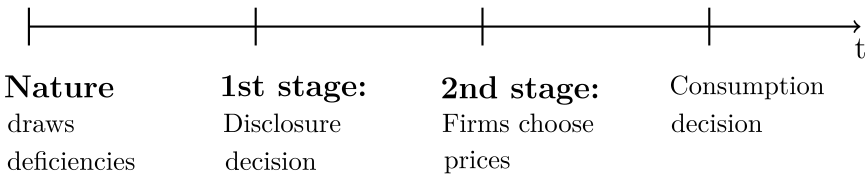


Figure 1: Timeline.

# 4 Results

We solve for the subgame-perfect Nash equilibria by backward induction.

## 4.1 Price-setting

In the price-setting stage, firms simultaneously and independently choose prices to maximize their profits. As the profit of each firm depends on the disclosure decisions in the

[5] Theoretically, the demand would become zero if firm $i$ chooses a price $p_i > v(1-\gamma) - \hat{d}_i + \gamma(\hat{d}_j + p_j)$. However, in equilibrium, firms will always choose prices such that both firms will receive a positive demand.

preceding stage, we distinguish three types of subgames: one subgame where neither firm discloses its deficiency, one subgame where only one firm discloses, and one subgame where both firms disclose.

First, if both firms remain silent (S), a fraction $\alpha\chi$ of consumers observes $d_1$ and $d_2$ perfectly, a fraction $\alpha(1-\chi)$ builds expectations about $d_1$ and $d_2$, and the remaining consumers do not take the deficiencies into account. Consequently, the profit of firm $i \in \{1,2\}$ equals:

$$\begin{aligned}\pi_i^{SS}(p_i,p_j) &= x_i^{SS}(p_i,p_j) \times p_i \\ &= \Big(\alpha\chi\frac{v(1-\gamma)-d_i-p_i+\gamma(d_j+p_j)}{1-\gamma^2} \\ &\quad + \alpha(1-\chi)\frac{v(1-\gamma)-E[d]-p_i+\gamma(E[d]+p_j)}{1-\gamma^2} \\ &\quad + (1-\alpha)\frac{v(1-\gamma)-p_i+\gamma p_j}{1-\gamma^2}\Big) \times p_i.\end{aligned}$$

Firm $i \in \{1,2\}$ chooses its price $p_i$ to maximize its profit. Therefore, in the subgame where both firms remain silent, by symmetry, firm $i \in \{1,2\}$ chooses price:

$$p_i^{SS} = \frac{v(2-\gamma-\gamma^2)-\alpha\chi(2-\gamma^2)d_i+\alpha\chi\gamma d_j-\alpha(1-\chi)(2-\gamma-\gamma^2)E[d]}{4-\gamma^2}. \tag{3}$$

The corresponding profit of firm $i \in \{1,2\}$ is:

$$\pi_i^{SS} = \frac{\left(p_i^{SS}\right)^2}{1-\gamma^2}.$$

Second, if only one firm discloses its deficiency, all consumers observe the deficiency of that firm perfectly. Furthermore, as soon as one firm makes its deficiency public, all consumers become aware of the existence of deficiencies, i.e., $\alpha = 1$. Yet, only a fraction $\chi$, i.e., experts, observes the deficiency of the other firm perfectly; amateurs, $1-\chi$, build expectations. Let firm $i$ be the disclosing firm (D) and let its competitor $j \neq i$ remain silent (S). Then, the profit of firm $i$ is:

$$\pi_i^{DS}(p_i,p_j) = x_i^{DS}(p_i,p_j) \times p_i = \frac{v(1-\gamma)-p_i-d_i+\gamma\Big(\chi d_j+(1-\chi)E[d]+p_j\Big)}{1-\gamma^2} \times p_i.$$

In contrast, the profit of firm $j \neq i$ is:

$$\pi_j^{DS}(p_i,p_j) = x_j^{DS}(p_i,p_j) \times p_j = \frac{v(1-\gamma)-p_j-\Big(\chi d_j+(1-\chi)E[d]\Big)+\gamma(d_i+p_i)}{1-\gamma^2} \times p_j.$$

Firms maximize their profits, yielding the following equilibrium prices:

$$p_i^{DS} = \frac{v(2-\gamma-\gamma^2) - (2-\gamma^2)d_i + \gamma\Big(\chi d_j + (1-\chi)E[d]\Big)}{4-\gamma^2}, \tag{4}$$

$$p_j^{DS} = \frac{v(2-\gamma-\gamma^2) + \gamma d_i - (2-\gamma^2)\Big(\chi d_j + (1-\chi)E[d]\Big)}{4-\gamma^2}. \tag{5}$$

The corresponding profits when only firm $i$ discloses are:

$$\pi_i^{DS} = \frac{\left(p_i^{DS}\right)^2}{1-\gamma^2},$$
$$\pi_j^{DS} = \frac{\left(p_j^{DS}\right)^2}{1-\gamma^2}.$$

Third, if both firms disclose their deficiencies, all consumers observe $d_1$ and $d_2$ perfectly, i.e., $\alpha = 1$ and $\chi = 1$, and the profit of firm $i \in \{1, 2\}$ is:

$$\pi_i^{DD}(p_i, p_j) = x_i^{DD}(p_i, p_j) \times p_i = \frac{v(1-\gamma) - p_i - d_i + \gamma(d_j + p_j)}{1-\gamma^2} \times p_i.$$

By symmetry, firm $i \in \{1, 2\}$ chooses price:

$$p_i^{DD} = \frac{v(2-\gamma-\gamma^2) - (2-\gamma^2)d_i + \gamma d_j}{4-\gamma^2}. \tag{6}$$

The corresponding profit of firm $i \in \{1, 2\}$ is thus:

$$\pi_i^{DD} = \frac{\left(p_i^{DD}\right)^2}{1-\gamma^2}.$$

## 4.2 Disclosure decision

In the disclosure stage, firms decide simultaneously and independently whether to disclose. They either disclose their true deficiency or remain silent. Table 2 illustrates the reduced game of the firms in the disclosure stage.

| | | Firm 2 | |
|---|---|---|---|
| | | *Disclose* | *Silent* |
| Firm 1 | *Disclose* | $\pi_1^{DD}, \pi_2^{DD}$ | $\pi_1^{DS}, \pi_2^{DS}$ |
| | *Silent* | $\pi_1^{SD}, \pi_2^{SD}$ | $\pi_1^{SS}, \pi_2^{SS}$ |

Table 2: Game matrix of the disclosure decision.

Four different subgame-perfect equilibria are possible: one where neither firm discloses, (S,S); two where only one firm discloses, (S,D) or (D,S); and one where both firms disclose, (D,D). Proposition 1 summarizes the existence conditions for each equilibrium.

**Proposition 1 (Subgame-perfect Nash equilibria)**
*(i) There exists a subgame-perfect Nash equilibrium where both firms disclose and choose prices given in* (6) *if and only if for all* $i \in \{1, 2\}$

$$d_i \leq E[d].$$

*(ii) There exists a subgame-perfect Nash equilibrium where firm* $i \in \{1, 2\}$ *discloses, firm* $j \in \{1, 2\}$ *with* $i \neq j$ *remains silent, and firms choose prices given in* (4) *and* (5) *if and only if*

$$d_j \geq E[d] \text{ and } d_i(2-\gamma^2)(1-\alpha\chi) - d_j\gamma\chi(1-\alpha) \leq E[d](1-\chi)\Big(\alpha(2-\gamma-\gamma^2)+\gamma\Big).$$

*(iii) There exists a subgame-perfect Nash equilibrium where both firms remain silent and choose prices given in* (3) *if and only if for all* $i, j \in \{1, 2\}$ *and* $i \neq j$

$$d_i(2-\gamma^2)(1-\alpha\chi) - d_j\gamma\chi(1-\alpha) \geq E[d](1-\chi)\Big(\alpha(2-\gamma-\gamma^2)+\gamma\Big).$$

The proof is in the Appendix. Proposition 1 shows that, in contrast to the unraveling result, we also find situations where neither firm discloses. The market unravels fully, i.e., both firms disclose, if and only if both firms' true deficiencies are smaller than consumers' expectations, i.e., $d_i \leq E[d]$ for all $i \in \{1, 2\}$. This means if $d_i \leq E[d]$ for all $i \in \{1, 2\}$, neither firm has an incentive to unilaterally deviate from disclosing to remaining silent. If both firms disclose, all consumers observe the deficiencies of both firms perfectly. If firm $i \in \{1, 2\}$ instead deviates to remaining silent, all consumers are still aware of the existence of deficiencies and perfectly observe the disclosing firm's deficiency. Thus, by remaining silent a firm only affects the amateurs' perceived deficiencies of its own good. If the firm discloses, amateurs perceive the true deficiency. If the firm remains silent, amateurs build expectations about the deficiency. As $d_i \leq E[d]$ for all $i \in \{1, 2\}$, amateurs have a lower willingness to pay (WTP) for the good of firm $i$, when firm $i$ remains silent and firm $j \neq i$ discloses compared to when both firms disclose. Consequently, neither firm has an incentive to unilaterally deviate from disclosing and a subgame-perfect equilibrium exists where both firms disclose.

However, the subgame-perfect Nash equilibrium in which both firms disclose need not be unique. Panel (a) of Figure 2 illustrates a situation where, for $d_i \leq E[d]$ for all $i \in \{1, 2\}$, a second subgame-perfect Nash equilibrium exists in which both firms remain silent, if $\alpha$ is sufficiently low relative to $\chi$. If both firms remain silent, aware experts perceive the true deficiencies of both firms, aware amateurs build expectations, and all unaware consumers perceive no deficiency. If firm $i$ unilaterally deviates and discloses, aware amateurs and all unaware consumers receive more information and perceive the deficiency of firm $i$ perfectly, i.e., $\hat{d}_i = d_i$. Consequently, they adjust their WTP. On the one hand, aware amateurs, i.e., a fraction $\alpha(1-\chi)$ of consumers, adjust their WTP upwards as $d_i \leq E[d]$. On the other hand, unaware consumers, i.e., a fraction $(1-\alpha)$ of consumers, adjust their WTP downwards as $d_i > 0$.[6] If $\alpha$ is low relative to $\chi$, the second effect dominates such that the firms have no incentive to deviate from remaining silent. Thus, if $d_i \leq E[d]$ for all $i \in \{1,2\}$ and $\alpha$ is sufficiently low relative to $\chi$, a second subgame-perfect equilibrium exists in which both firms remain silent.

If $d_i > E[d]$ for at least one firm $i \in \{1,2\}$, either one firm remains silent and one firm discloses or both firms remain silent. These subgame-perfect Nash equilibria are unique. Panel (b) of Figure 2 depicts such a situation. For sufficiently low $\alpha$ relative to $\chi$ both firms remain silent; otherwise, the firm with the lower deficiency discloses. The existence of each equilibrium depends on the adjustment of the WTP. The firm with the higher deficiency never has an incentive to disclose because disclosure decreases the WTP of all unaware consumers ($d_i > 0$) and of all aware amateurs ($d_i > E[d]$) and, therefore, reduces the firm's profits. In addition, a comparison with its competitor hurts the firm with the higher deficiency if it discloses.

If the firm with the lower deficiency discloses, the WTP of unaware consumers decreases ($d_i > 0$). The WTP of aware amateurs increases if $d_i < E[d]$ and decreases if $d_i > E[d]$. Aware experts' WTP is unaffected. In addition, by disclosing the firm educates consumers about the deficiency of its competitor. Former unaware experts are now perfectly aware of both deficiency levels. Former unaware amateurs now build expectations about the silent firm's deficiency. Thus, disclosure not only exerts a negative externality on the opponent silent firm but also reduces the negative adjustment effect on the WTP of unaware consumers for the disclosing firm. Therefore, both firms remain silent if both deficiencies are similarly high. Panels (c) and (d) of Figure 2 highlight this.

In the following, we focus on the conditions for the existence of the subgame-perfect equilibrium where both firms remain silent. We analyze the effects of different deficiencies as well as the composition of the consumer side on the existence of this equilibrium. In addition, we analyze how increased competition influences firms' incentives to remain silent.

[6]Unaware experts now also perceive the deficiency of the silent firm perfectly. Unaware amateurs build expectations about the silent firm's deficiency. This also affects the willingness to pay for the disclosing firm's good.

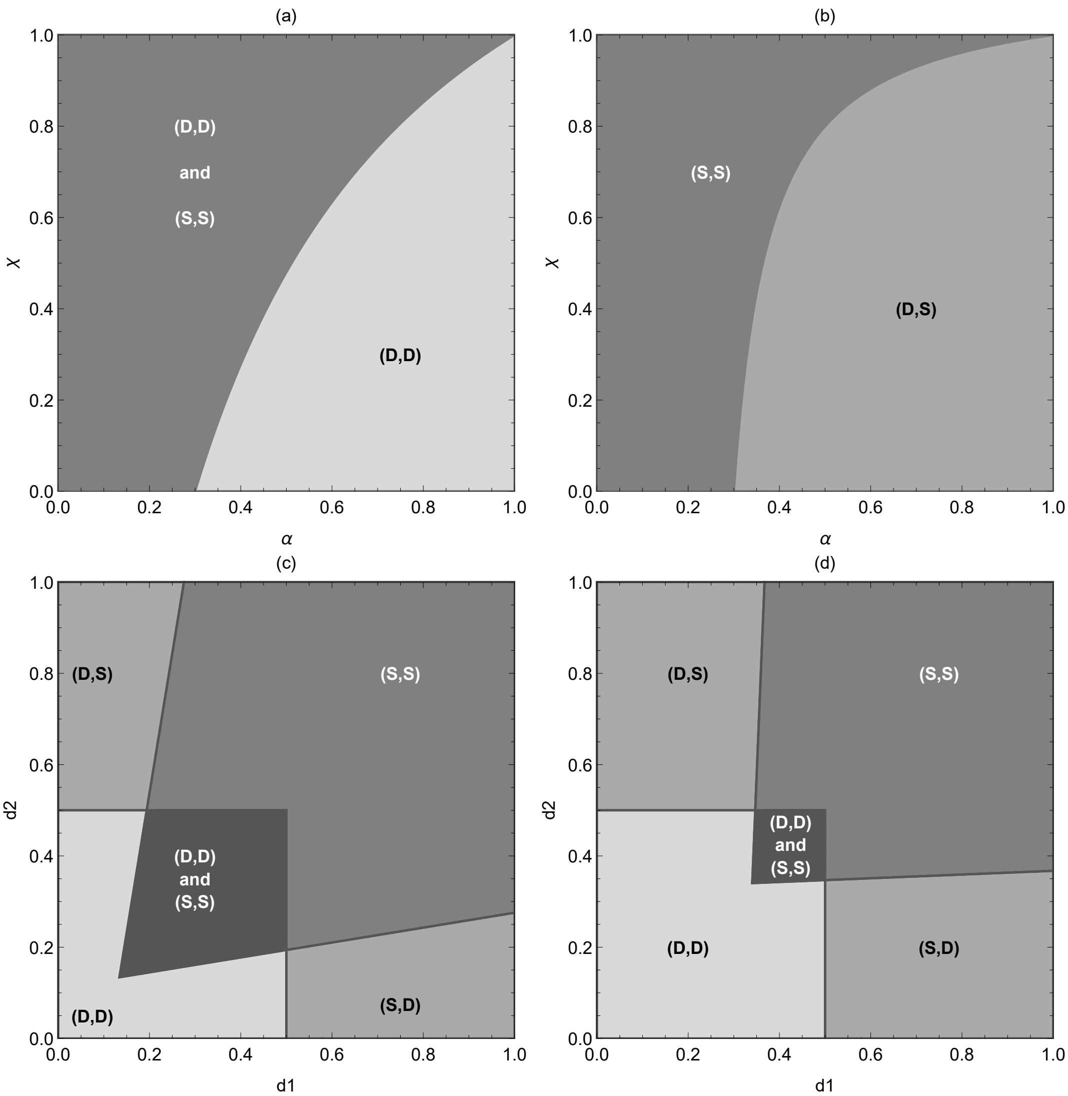


Figure 2: Disclosure decisions with $E[d] = 1/2$ and $\gamma = 1/2$. For (a): $d_1 = 1/4$ and $d_2 = 1/3$. For (b): $d_1 = 1/4$ and $d_2 = 3/4$. For (c): $\alpha = 1/3$ and $\chi = 2/3$. For (d): $\alpha = 2/3$ and $\chi = 1/3$.

## 4.3 Comparative statics

Note that both firms remain silent if

$$d_1(2-\gamma^2)(1-\alpha\chi) - d_2\gamma\chi(1-\alpha) \geq E[d](1-\chi)\Big(\alpha(2-\gamma-\gamma^2)+\gamma\Big) \tag{7}$$

and

$$d_2(2-\gamma^2)(1-\alpha\chi) - d_1\gamma\chi(1-\alpha) \geq E[d](1-\chi)\Big(\alpha(2-\gamma-\gamma^2)+\gamma\Big). \tag{8}$$

If $d_1 \leq d_2$, (7) is binding. Otherwise (8) is binding. Without loss of generality, in the following we assume $d_1 \leq d_2$ and let

$$\tau \equiv d_1(2-\gamma^2)(1-\alpha\chi) - d_2\gamma\chi(1-\alpha) - E[d](1-\chi)\Big(\alpha(2-\gamma-\gamma^2)+\gamma\Big).$$

Then, Proposition 1 (*iii*) holds if $\tau \geq 0$. The existence condition, i.e., $\tau \geq 0$, is derived from a comparison of the profits of firm 1 when both firms remain silent and when only firm 1 discloses. $\tau$ increases if the profit of firm 1 for remaining silent increases compared to its profit when it discloses.

### 4.3.1 Actual and expected deficiencies

The existence of a subgame-perfect equilibrium where both firms remain silent depends on the firms' actual deficiencies as well as the expected deficiencies.

First, the range of values for which both firms remain silent increases, if the deficiency of the firm with the binding constraint increases:

$$\frac{\partial \tau}{\partial d_1} = (2-\gamma^2)(1-\alpha\chi) > 0.$$

If firm 1 discloses, all consumers will take the true deficiency of firm 1 into account. The higher the deficiency of firm 1, the lower the WTP for the good of firm 1. Thus, the higher $d_1$, the less firm 1 profits from disclosing.

Second, the range of values for which both firms remain silent decreases, if the deficiency of the firm with the higher deficiency increases:

$$\frac{\partial \tau}{\partial d_2} = -\gamma\chi(1-\alpha) < 0.$$

If firm 1 discloses, more consumers will take the true deficiency of firm 2 into account. Former unaware experts now know the true deficiency. The higher the deficiency of firm 2, the higher the WTP for the good of firm 1. Thus, the higher $d_2$, the more firm 1 profits from disclosing.

Third, the range of values for which both firms remain silent decreases in the expected deficiency, $E[d]$:

$$\frac{\partial \tau}{\partial E[d]} = -(1-\chi)\Big(\alpha(2-\gamma-\gamma^2)+\gamma\Big) < 0.$$

If both firms remain silent, an increase in $E[d]$ implies that aware amateurs' WTP decreases. In other words, aware amateurs become more skeptical towards the deficiencies of good 1 *and* good 2. In contrast, if firm 1 discloses, all consumers observe the true deficiency of firm 1 and amateurs build expectations only about the good of firm 2. Then, an increase in $E[d]$ increases the WTP for the good of firm 1. In sum, if $E[d]$ increases, firm 1 discloses for a larger range of values. This effect can be attributed to changes in skepticism: The more skeptical consumers are towards firms, the more transparent firms become.

### 4.3.2 Consumer types

The existence of the equilibrium, where both firms remain silent, also hinges on the fraction of aware and expert consumers in the market. In general, an increase in awareness has the subsequent effect on $\tau$:

$$\frac{\partial \tau}{\partial \alpha} = -(2-\gamma^2)\left(\chi d_1 + (1-\chi)E[d]\right) + \gamma\left(\chi d_2 + (1-\chi)E[d]\right). \tag{9}$$

If both firms remain silent, an increase in $\alpha$ affects the WTP for good 1 in four ways: First, if $\alpha$ increases, more consumers observe $d_1$ perfectly which decreases the average WTP for the good of firm 1. Second, if $\alpha$ increases, more consumers build expectations about the deficiency of firm 1 and, as $E[d] > 0$, this decreases the average WTP for the good of firm 1. Third, if $\alpha$ increases, more consumers observe $d_2$ perfectly which increases the average WTP for the good of firm 1. Fourth, if $\alpha$ increases, more consumers build expectations about the deficiency of firm 2 and, as $E[d] > 0$, this increases the average WTP for the good of firm 1. Whether in sum, the WTP for the good of firm 1 increases or decreases depends on the substitutability between the goods, $\gamma$. If $\gamma \to 0$, only the effects on $d_1$ and on the expectations about $d_1$ matter. If $\gamma \to 1$, the effects on the deficiencies (actual and expected) of firm 1 and firm 2 carry equal weight. In sum, for low levels of substitutability, the motivation to inform consumers about its own quality affects firm 1's decision to disclose. For high levels of substitutability, the decision of firm 1 to disclose is also affected by the motivation to inform consumers about its rival's quality.

In contrast, if firm 1 discloses and firm 2 remains silent, an increase in the initial fraction of aware consumers has no effect, because the disclosure already yields full awareness.

Corollary 1 summarizes this:[7]

[7]See Appendix B for a detailed derivation.

**Corollary 1**
*There exists a $\gamma'$ such that*

*(i) $\partial\tau/\partial\alpha < 0$ if and only if $\gamma < \gamma'$ and*

*(ii) $\partial\tau/\partial\alpha > 0$ if and only if $\gamma > \gamma'$.*

The fraction of experts $\chi$ also affects firms' incentives to disclose:

$$\frac{\partial\tau}{\partial\chi} = -d_1(2-\gamma^2)\alpha - d_2\gamma(1-\alpha) + E[d]\Big(\alpha(2-\gamma-\gamma^2)+\gamma\Big). \tag{10}$$

If both firms remain silent, an increase in $\chi$ has the following effects on the WTP for the good of firm 1 and thus also on the profit of firm 1: First, as $\chi$ increases, more consumers observe the true deficiency of firm 1 instead of building expectations about $d_1$. This increases (decreases) the WTP for the good of firm 1, if $d_1 < E[d]$ ($d_1 > E[d]$). Second, as $\chi$ increases, more consumers observe the true deficiency of firm 2, instead of building expectations about $d_2$. This increases (decreases) the WTP for the good of firm 1, if $d_2 > E[d]$ ($d_2 < E[d]$). In addition, the fraction of aware consumers affects how pronounced the changes in WTP are: The higher $\alpha$, the more pronounced are the changes in WTP when both firms remain silent.

In contrast, if only firm 1 discloses and $\chi$ increases, more consumers observe the true deficiency of firm 2, instead of building expectations about $d_2$. This increases (decreases) the WTP, if $d_2 > E[d]$ ($d_2 < E[d]$).

Then, $\tau$ increases if the profit of firm 1 for remaining silent increases compared to its profit when it discloses. Corollary 2 summarizes the effect of $\chi$ on $\tau$:[8]

**Corollary 2**
*There exists a $\alpha'$ such that*

*(i) $\partial\tau/\partial\chi < 0$ if and only if $E[d] < d_1 < d_2$ or $d_1 < E[d] < d_2$ with $\alpha < \alpha'$ and*

*(ii) $\partial\tau/\partial\chi > 0$ if and only if $d_1 < E[d] < d_2$ with $\alpha > \alpha'$ or $d_1 < d_2 < E[d]$.*

#### 4.3.3 Competitive pressure

The parameter $\gamma$ captures the substitutability between good 1 and good 2. If $\gamma = 0$, the goods are unrelated and both firms operate as monopolists; if $\gamma = 1$, the goods are perfect substitutes. Thus, $\gamma$ measures the *competitive pressure* and is essential for a policy analysis.

The impact of competitive pressure on $\tau$ is:

$$\frac{\partial\tau}{\partial\gamma} = -2\gamma d_1(1-\alpha\chi) - \chi d_2(1-\alpha) + E[d](1-\chi)(\alpha(1+2\gamma)-1). \tag{11}$$

[8] See Appendix B for a detailed derivation.

Increasing competition does not always reduce the range of values for which both firms remain silent. The effect depends on the deficiencies and the composition of the consumer side. Increasing the competitive pressure has two main effects.

First, as $\gamma$ increases, consumers put more weight on $d_2$ relative to $d_1$. This increases the WTP for the good of firm 1 if both firms remain silent as well as when only firm 1 discloses. However, the effect is more pronounced when firm 1 discloses, because when both firms remain silent only aware experts take $d_1$ and $d_2$ into account. In consequence, this effect incentivices firm 1 to disclose.

Second, if both firms remain silent, a fraction $\alpha(1-\chi)$ of consumers builds expectations about the deficiencies of firm 1 and firm 2 such that $E[d_1] = E[d_2]$. If $\gamma = 0$, consumers' WTP for the good of firm 1 is independent of the expected deficiency of firm 2. Whereas, if $\gamma = 1$, consumers' WTP for the good of firm 1 depends equally on the expected deficiencies of good 1 and good 2. Thus, as $\gamma$ increases the expected deficiencies become less important such that the WTP for the good of firm 1 increases. In contrast, if firm 1 discloses, all consumers observe the deficiency of firm 1 perfectly, only amateurs build expectations about the deficiency of firm 2. An increase in $\gamma$ then benefits firm 1. This second effect incentivices firm 1 to remain silent if $\alpha$ is sufficiently large.

In sum, for a sufficiently high $\alpha$, the range of values for which both firms remain silent may increase. That means, if a large fraction of consumers is aware, high competitive pressure is not optimal. Corollary 3 summarizes this:[9]

**Corollary 3**
*There exists a $\alpha''$ such that*

*(i) $\partial\tau/\partial\gamma < 0$ if and only if $E[d] < d_1$ or $E[d] > d_1$ with $\alpha < \alpha''$ and*

*(ii) $\partial\tau/\partial\gamma > 0$ if and only if $E[d] > d_1$ with $\alpha > \alpha''$.*

# 5 Extension: Investments in quality

In this section, we allow firms to invest in quality. In particular, we allow firms to invest to eliminate the deficiency of their good. Yet, in line with the interpretation of the probabilistic occurrence of deficiencies not all investments are successful. Each firm can invest $\rho_i \in [0, 1]$ to obtain deficiency $d_i = 0$ with probability $\rho_i$ and deficiency $d_i = 1$ with probability $1 - \rho_i$. If a firm invests $\rho_i$, it incurs costs $C(\rho_i) = c\rho_i^2$ with $c > 0$. We assume that consumers remain oblivious to the investment decisions of the firms.

Firms now play a three-stage game (see Figure 3): In the first stage, both firms choose their investment $\rho_i$. In the second stage, after observing the investment of their competitor each firm decides whether to disclose. In the third stage, both firms choose prices. The solution of the price-setting and the disclosure decision are identical to Section 4.

[9] See Appendix B for a detailed derivation.


Figure 3: Timeline.

In the first stage, both firms consider the four possible outcomes of the investment decisions: (i) both firms' deficiencies are 0, (ii) and (iii) one firm's deficiency is 0 and the other firm's deficiency is 1, and (iv) both firms' deficiencies are 1. The profit of firm $i \in \{1,2\}$ is thus:

$$\begin{aligned}\pi_i(\rho_i,\rho_j) =& \rho_i\rho_j \times \pi_i(0,0) + \rho_i(1-\rho_j) \times \pi_i(0,1) + (1-\rho_i)\rho_j \times \pi_i(1,0) \\ &+ (1-\rho_i)(1-\rho_j) \times \pi_i(1,1) - C(\rho_i).\end{aligned}$$

It follows from Proposition 1 that each possible combination of deficiencies, i.e., $(d_i, d_j)$ with $d_i \in \{0,1\}$ and $d_j \in \{0,1\}$, leads to one specific disclosure outcome. If both firms obtain low deficiencies, $d_1 = d_2 = 0$, Proposition 1 $(i)$ is fulfilled and both firms disclose. If both deficiencies are high, $d_1 = d_2 = 1$, Proposition 1 $(iii)$ is fulfilled and neither firm discloses. If the deficiency levels differ, Proposition 1 $(ii)$ is fulfilled and the firm with the higher deficiency remains silent and the firm with the lower deficiency discloses. Accordingly, the profit function of firm $i \in \{1,2\}$ reduces to:

$$\pi_i(\rho_i,\rho_j) = \rho_i\rho_j\pi_i^{DD} + \rho_i(1-\rho_j)\pi_i^{DS} + (1-\rho_i)\rho_j\pi_i^{SD} + (1-\rho_i)(1-\rho_j)\pi_i^{SS} - C(\rho_i).$$

Each firm $i$ chooses $\rho_i$ to maximize its profit. Proposition 2 summarizes the optimal investment choice.

**Proposition 2 (Investment)**
*Let*

$$\begin{aligned}\bar{\chi} &\equiv \chi + (1-\chi)E[d], \\ \bar{\gamma} &\equiv= 2 - \gamma - \gamma^2, \\ \bar{v} &\equiv \frac{\bar{\chi}^2(2-\gamma^2)^2 + 2c(1-\gamma^2)(4-\gamma^2)^2}{2\bar{\gamma}\bar{\chi}(2-\gamma^2)}.\end{aligned}$$

*In the subgame-perfect Nash equilibrium, for all* $i \in \{1,2\}$*:*

*(i)* $\rho_i^* = 1$ *if* $v \geq \bar{v}$

*(ii)* $\rho_i^* = \dfrac{2v\bar{\chi}\bar{\gamma}\left(\gamma+\alpha\bar{\gamma}\right)+\bar{\chi}^2\left(\gamma^2-\alpha^2\bar{\gamma}^2\right)}{2c(1-\gamma^2)(4-\gamma^2)^2-\bar{\chi}\bar{\gamma}^2\left(2v(1-\alpha)+\alpha^2\bar{\chi}\right)+\bar{\chi}^2\left(\gamma^2+(2-\gamma^2)^2\right)}$ *if* $v \leq \bar{v}$.

The proof of Proposition 2 is in the Appendix. In equilibrium, both firms choose $\rho_i^*$. $\rho_i^*$ is the probability that a firm produces goods with low deficiencies 0 and discloses.

Figure 4 shows the investment $\rho_i^*$ as a function of the initial fraction of aware consumers $\alpha$ for different values of $\gamma$. Generally, $\rho_i^*$ is increasing in $\alpha$.[10] If at least one firm produces a good without deficiency, that firm discloses and all consumers become aware of the possibility of deficiencies, i.e., $\alpha = 1$. In these cases, a change in the original fraction of aware consumers has no effect on the firms' profits. The original fraction of aware consumers $\alpha$ affects firms' profits only if both firms produce goods with deficiencies and remain silent. Then, an increase in $\alpha$ implies a reduction in the average willingness to pay of the consumers: For former unaware consumers the perceived deficiency becomes either $\hat{d}_i = d_i > 0$ or $\hat{d}_i = E[d] > 0$ instead of $\hat{d}_i = 0$. Consequently, firms choose lower prices and make less profit. To counter this reduction in profits, firms increase their investment $\rho_i$ such that the outcome $(Silent, Silent)$ becomes less likely. Therefore, an increase in $\alpha$ leads to an increase in $\rho_i^*$.

Firms invest more if the fraction of experts $\chi$ in the market increases (see Figure 4).[11] Two effects play a role here. First, an increase in $\chi$ reduces the profit of firm $i$ if firm $i$ produces a deficiency $d_i = 1$ and remains silent: An increase in $\chi$ implies that more consumers observe the true deficiency instead of building expectations, which reduces consumers' average willingness to pay. Consequently, firm $i$ has an incentive to avoid these cases by investing more. Second, an increase in $\chi$ increases the profit of firm $i$ if its deficiency is $d_i = 0$ and its competitor's deficiency is $d_j = 1$, because more consumers observe the true deficiency of the competitor which is higher than expected. In consequence, an increase in $\chi$ induces firms to invest more to avoid the loss in profits associated with their own high deficiencies and to increase the gain in profits associated with having the better product than the competitor. Thus, the higher the fraction of experts, the higher the investments.

Figure 4 illustrates the effects of competition on investments in quality. Whether increasing competition induces firms to invest more or less depends to a large extent on the consumer side.[12] If there are only few aware consumers in the market, a monopolist invests less than a duopolist. With few aware consumers, most consumers do not take deficiencies into account. A monopolist thus has no incentives to invest to reduce his deficiency. In contrast, duopolists want to invest and disclose the existence of deficiencies to distinguish themselves from their competitor and attract more consumers. Consequently, if $\alpha$ is low, competitive pressure increases investments.

However, if $\alpha$ is high, competitive pressure reduces investments. If $\alpha$ is high, a mo-

[10]See Appendix D for a detailed analysis of $(\partial\rho_i^*)/(\partial\alpha)$.

[11]See Appendix D for a detailed analysis of $(\partial\rho_i^*)/(\partial\chi)$.

[12]See Appendix D for a detailed analysis of $(\partial\rho_i^*)/(\partial\gamma)$. In general, there exists a $\bar{\alpha}$ such that $(\partial\rho_i^*)/(\partial\gamma) > 0 \Leftrightarrow \alpha < \bar{\alpha}$. For example, for $E[d] = 1/2$, $v = 5$, $c = 1$, and $\chi = \frac{1}{2}$, $0 \leq \bar{\alpha} \leq 1$. However, $0 \leq \bar{\alpha} \leq 1$ is not always fulfilled.

nopolist has an incentive to invest because this allows him to charge all consumers higher prices. In contrast, duopolists cannot fully collect the additional willingness to pay that arises when firms have lower deficiencies, as they share the surplus with their competitor. Thus if $\alpha$ is high, a monopolist invests more than a duopolist.

The exact threshold where increasing competitive pressure becomes detrimental also depends on the fraction of experts in the market, because these experts take the true deficiency of the competitor into account: As $d_j = 1 > E[d]$, a firm that discloses benefits more if consumers observe the true deficiency of its silent competitor. In sum, increasing competition is not universally beneficial for investments in deficiency reductions and corresponding disclosure.

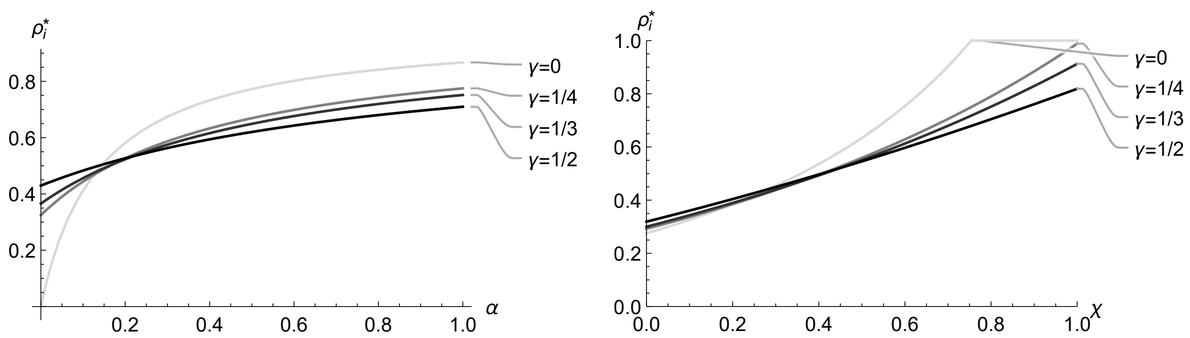


Figure 4: On the left side, investment in quality, $\rho_i^*$, as a function of the fraction of aware consumers $\alpha$, with $E[d] = 1/2$, $v = 5$, $c = 1$, and $\chi = \frac{1}{2}$. On the right side, investment in quality, $\rho_i^*$, as a function of expert consumers $\chi$, with $E[d] = 1/2$, $v = 5$, $c = 1$, and $\alpha = \frac{1}{4}$.

# 6 Policy implications

Market authorities aim to achieve a high level of market transparency, i.e., unraveling, in order to ensure that consumers can make informed purchasing decisions. In our model, this translates to all firms disclosing their product information. Yet, as our results show the unraveling result does not always hold (see Proposition 1). Dependent on the fraction of aware and expert consumers, firms find it optimal to remain silent. Additionally, if firms can invest to reduce deficiencies, firms choose their investment, $\rho_i^*$, according to the profitability of each possible market outcome. This does not always lead to full unraveling (see Proposition 2). This leaves room for market authorities to increase market transparency.

In the following, we discuss the effects of information campaigns, facilitating competition, as well as a minimum standard. These measures differ with regard to the targeted market side as well as to their directness. We argue that information campaigns change the composition of consumer types. Therefore, information campaigns as well as facilitating competition, *indirectly* affects firms' incentives to disclose and to invest. In contrast, a minimum standard either affects the range of deficiencies or forces firms to make a minimum investment, $\rho_i \in [\underline{\rho}, 1]$. Thus, a minimum standard *directly* steers investments.

## 6.1 Information campaign

One possible intervention that market authorities regularly use is an information campaign. Information campaigns apply to two features of our model: First, information campaigns attract consumers' awareness to a particular topic and inform consumers of the possibility of deficiencies, i.e., they increase $\alpha$. Second, information campaigns can increase the amount of experts in the market, i.e., they increase $\chi$.

To increase awareness in a market, the market authority can place advertisements. Voluntary labels and certificates can also increase the awareness of consumers. One recent example is the "green button" that the German federal government implemented. This campaign aims to increase awareness towards sustainable and ecological products in the fashion industry. In addition to inventing the voluntary label, the German federal government placed advertisements highlighting the role of sustainable products. Furthermore, the introduction of new labels is often discussed in the media and therefore further increases awareness among consumers. Whether this increase in awareness is sufficient to unravel the market, i.e., $(\partial\tau)/(\partial\alpha) < 0$, depends on the competitive pressure within the market, i.e., $\gamma$: According to Corollary 1, an information campaign *indirectly* leads a firm to disclose, if the competitive pressure in the market is sufficiently low.

An information campaign can also increase the amount of experts $\chi$ in the market. Examples of such information campaigns include increased learning opportunities, education programs, and advanced scientific training. Corollary 2 shows that whether increasing the fraction of experts in the market leads to more disclosure depends on the deficiencies of the firms relative to the expected deficiencies as well as the fraction of aware consumers in the market.

Overall, by increasing awareness and expertise, information campaigns make consumers less dependent on firms' disclosure in the short term. However, increasing awareness and/or expertise might reduce disclosure in the market. Furthermore, increasing awareness and/or expertise changes the profit of firms. For example, if the competitive pressure is high, an increase in awareness makes remaining silent more profitable relative to disclosing. Thus, although information campaigns increase transparency in a market directly by increasing awareness and/or expertise, they might not induce full transparency because they do not always induce disclosure by firms.

In contrast, in the long term where firms can invest in quality, an increase in awareness, $\alpha$, or in expertise, $\chi$, puts pressure on firms to increase their investments in quality, see Figure 4. Consequently, an information campaign has two effects. First, information campaigns target the demand side and directly inform some consumers. Second, increases in

$\alpha$ and $\chi$ through the information campaign indirectly raise market transparency: The increased awareness and expertise incentivices firms to increase their investments in quality and subsequently disclose their deficiencies.

The strictest intervention to implement by a market authority is a mandatory label where firms always have to disclose their deficiencies. In our model, this intervention eliminates all equilibria except full disclosure.

## 6.2 Facilitating competition

A market authority can facilitate competition, for example, by enforcing antitrust laws or dismantling entry barriers. In addition, the use of information campaigns, in particular labels and certificates, may facilitate competition among firms. For example, a market authority can restrict the number of voluntary labels or certificates such that firms must not use any other label than the voluntary label implemented by the market authority if they want to disclose their deficiency. Thereby, a market authority establishes one platform for firms' disclosure. Thus, the market authority increases competition by increasing the comparability of products and prevents firms from avoiding competition by pretending to sell differentiated goods.

The effect of facilitated competition on the market outcome, i.e., $(\partial\tau)/(\partial\gamma)$ in the short term and $(\partial\rho_i^*)/(\partial\gamma)$ in the long term, depends on the fraction of aware consumers relative to the fraction of expert consumers in the market (see Corollary 3 and Section 5). Facilitating competition, i.e., an increase in $\gamma$, only increases disclosure if the fraction of aware consumers is sufficiently low. Otherwise, facilitating competition increases the incentives of firms to remain silent.

## 6.3 Minimum standard

A market authority can also target the supply side directly to induce a transparent market outcome, for example, by introducing a minimum standard. In the short term, a market authority can restrict market access to firms with deficiencies $d_i < \bar{d}$. In the long term, a market authority can require firms to invest a minimum in the probability of producing low deficiencies, i.e., $\rho \in [\underline{\rho}, 1]$.

In the short term, a minimum standard affects $d_1, d_2 \in [0, \bar{d}]$. This measure prevents firms from selling any good with deficiency $d_i > \bar{d}$. Additionally, by implementing $\bar{d}$ the distribution regarding consumers' expectations shift downwards, i.e., $E[d]_{new} < E[d]_{old}$. As $(\partial\tau)/(\partial E[d]) < 0$, this change in expectations increases the range of values for which a transparent market outcome occurs.

In the long term, a market authority can implement $\underline{\rho} = 1$ such that both firms will disclose their deficiency levels with certainty. This intervention ensures that all firms disclose in equilibrium. A less restrictive measure, which also increases the chances of a full disclosure outcome, is to require a minimum investment, $\underline{\rho} < 1$. Yet, if a long term minimum standard is introduced, aware consumers may account for the minimum standard by adjusting their expectations, i.e., $E[d]_{new} < E[d]_{old}$. This may induce both firms to remain silent: According to Proposition 2, firms invest less to reduce the deficiency.[13]

The determination of the exact threshold of a minimum standard, $\underline{\rho}$, is an impediment which the market authority needs to consider. A market authority has to have perfect knowledge of the optimal investment decision by firms in order to successfully achieve a higher market transparency: Any minimum standard $\underline{\rho} < \rho_i^*$ will have no effect on the market transparency.

# 7 Conclusion

The aim of this article is to analyze the effects of frictions on the demand side, i.e., awareness and expertise, on the disclosure decision of the supply side. We also investigate the effects of consumer awareness and expertise on firms' investments in quality and subsequent disclosure of deficiencies. In addition, we examine the effects of competitive pressure on market transparency.

Our findings clearly indicate that the market outcome depends markedly on the awareness and expertise of consumers. In addition, we show that increasing the competitive pressure in the market does not universally increase the incentives to disclose: If the fraction of aware consumers is sufficiently high relative to the fraction of expert consumers, more competition may lead to less disclosure.

Similarly, we find that more competition does not necessarily induce a firm to invest more in quality and to disclose its deficiencies. We find that if the fraction of aware consumers in the market is low relative to the fraction of expert consumers, a firm invests more the more intense the competition. But, if many consumers in the market are aware of deficiencies, a monopolist invests more than a firm that faces competition.

Taken together, these results suggest that market authorities can intervene to increase market transparency. We discuss information campaigns and minimum standards. We show that neither information campaigns nor minimum standards universally induce firms to disclose. In addition, with information campaigns as well as minimum standards, the market authority needs a good understanding of the possible deficiencies of goods. In cases where the market authority itself is unaware of a particular deficiency, such as in the FFP2 masks case in the beginning of 2020, the market authority is unable to provide information campaigns or implement minimum standards. In contrast, facilitating competition is still possible. Although, facilitating competition need not have the intended effect of increasing transparency, in situations of extreme unawareness where the market authority is unaware

[13] As $(\partial \rho_i^*)/(\partial E[d]) \geq 0$, if $E[d]$ decreases, the probability that firms disclose decreases.

as well, facilitating competition increases the incentives of firms to disclose in the short term.

# A Proof Proposition 1

(i) Both firms disclosing with prices given in (6) is a subgame-perfect Nash equilibrium if and only if

$$\pi_1^{DD} \geq \pi_1^{SD} \text{ and } \pi_2^{DD} \geq \pi_2^{DS} \;\Leftrightarrow\; d_i \leq E[d] \text{ for all } i \in \{1,2\}.$$

(ii) Only one firm disclosing with prices given in (4) and (5) is a subgame-perfect Nash equilibrium if and only if

$$\pi_1^{DS} \geq \pi_1^{SS} \;\Leftrightarrow\; d_1(2-\gamma^2)(1-\alpha\chi) - d_2\gamma\chi(1-\alpha) \leq E[d](1-\chi)(\alpha(2-\gamma-\gamma^2)+\gamma)$$

and

$$\pi_2^{DS} \geq \pi_2^{DD} \;\Leftrightarrow\; d_2 \geq E[d]$$

or

$$\pi_1^{SD} \geq \pi_1^{DD} \;\Leftrightarrow\; d_1 \geq E[d]$$

and

$$\pi_2^{SD} \geq \pi_2^{SS} \;\Leftrightarrow\; d_2(2-\gamma^2)(1-\alpha\chi) - d_1\gamma\chi(1-\alpha) \leq E[d](1-\chi)(\alpha(2-\gamma-\gamma^2)+\gamma).$$

(iii) Both firms remaining silent with prices given in (3) is a subgame-perfect Nash equilibrium if and only if

$$\pi_1^{SS} \geq \pi_1^{DS} \text{ and } \pi_2^{SS} \geq \pi_2^{SD}$$

$$\Leftrightarrow d_i(2-\gamma^2)(1-\alpha\chi) - d_j\gamma\chi(1-\alpha) \geq E[d](1-\chi)\Big(\alpha(2-\gamma-\gamma^2)+\gamma\Big) \text{ for all } i \in \{1,2\}.$$

# B Proof Corollary 1 - 3

Let:

$$\tau \equiv d_1(2-\gamma^2)(1-\alpha\chi) - d_2\gamma\chi(1-\alpha) - E[d](1-\chi)\Big(\alpha(2-\gamma-\gamma^2)+\gamma\Big)$$

such that $\tau \geq 0$ is the condition for which Proposition 1 (*iii*) holds.

**Corollary 1** is derived by analyzing the derivative of $\tau$ with respect to $\alpha$:

$$\begin{aligned}
&\frac{\partial\tau}{\partial\alpha} > 0 \\
\Leftrightarrow\ & -d_1(2-\gamma^2)\chi + d_2\gamma\chi - E[d](1-\chi)(2-\gamma-\gamma^2) > 0 \\
\Leftrightarrow\ & \gamma > \gamma' \equiv -\frac{1}{2}\frac{d_2\chi + E[d](1-\chi)}{d_1\chi + E[d](1-\chi)} + \sqrt{2 + \Big(\frac{1}{2}\frac{d_2\chi + E[d](1-\chi)}{d_1\chi + E[d](1-\chi)}\Big)^2}
\end{aligned}$$

or

$$\gamma < -\frac{1}{2}\frac{d_2\chi + E[d](1-\chi)}{d_1\chi + E[d](1-\chi)} - \sqrt{2 + \Big(\frac{1}{2}\frac{d_2\chi + E[d](1-\chi)}{d_1\chi + E[d](1-\chi)}\Big)^2} < 0.$$

Thus $\frac{\partial\tau}{\partial\alpha} > 0 \ \Leftrightarrow \gamma > \gamma'$. In contrast, $\frac{\partial\tau}{\partial\alpha} < 0 \Leftrightarrow \gamma < \gamma'$.

**Corollary 2** is derived by analyzing the derivative of $\tau$ with respect to $\chi$:

$$\begin{aligned}
&\frac{\partial\tau}{\partial\chi} > 0 \\
\Leftrightarrow\ & -d_1(2-\gamma^2)\alpha - d_2\gamma(1-\alpha) + E[d]\Big(\alpha(2-\gamma-\gamma^2)+\gamma\Big) > 0 \\
\Leftrightarrow\ & \alpha\Big((2-\gamma^2)(E[d]-d_1) + \gamma(d_2 - E[d])\Big) > \gamma(d_2 - E[d]).
\end{aligned} \tag{12}$$

If $d_1 < E[d] < d_2$, then $\frac{\partial\tau}{\partial\chi} > 0$ if and only if

$$\alpha > \alpha' \equiv \frac{\gamma(d_2 - E[d])}{(2-\gamma^2)(E[d]-d_1) + \gamma(d_2 - E[d])}$$

and $\frac{\partial\tau}{\partial\chi} < 0$ if and only if $\alpha < \alpha'$. In addition, we can rewrite (12) such that

$$\begin{aligned}
&\frac{\partial\tau}{\partial\chi} > 0 \\
\Leftrightarrow\ & \alpha(2-\gamma^2)(E[d]-d_1) > (1-\alpha)\gamma(d_2 - E[d]).
\end{aligned} \tag{13}$$

If $d_1 < d_2 < E[d]$, the left hand side of (13) is positive and the right hand side of (13) is negative such that $\frac{\partial\tau}{\partial\chi} > 0$ is always fulfilled. Furthermore,

$$\begin{aligned}&\frac{\partial\tau}{\partial\chi} < 0\\ \Leftrightarrow\ &\alpha(2-\gamma^2)(E[d]-d_1) < (1-\alpha)\gamma(d_2 - E[d]).\end{aligned} \tag{14}$$

If $E[d] < d_1 < d_2$, the left hand side of (14) is negative and the right hand side of (14) is positive such that $\frac{\partial\tau}{\partial\chi} < 0$ is always fulfilled.

**Corollary 3** is derived by analyzing the derivative of $\tau$ with respect to $\gamma$:

$$\begin{aligned}&\frac{\partial\tau}{\partial\gamma} > 0\\ \Leftrightarrow\ & -2\gamma d_1(1-\alpha\chi) - \chi d_2(1-\alpha) + E[d](1-\chi)(\alpha(1+2\gamma)-1) > 0,\\ \Leftrightarrow\ &\alpha\Big(2d_1\chi\gamma + d_2\chi + E[d](1-\chi)(1+2\gamma)\Big) > 2d_1\gamma + d_2\chi + E[d](1-\chi)\\ \Leftrightarrow\ &\alpha > \alpha'' \equiv \frac{2d_1\gamma + d_2\chi + E[d](1-\chi)}{2d_1\chi\gamma + d_2\chi + E[d](1-\chi)(1+2\gamma)}.\end{aligned}$$

Note that $\alpha'' > 0$ is always fulfilled and

$$\alpha'' < 1 \Leftrightarrow d_1 < E[d].$$

Thus, if $d_1 < E[d]$, $\frac{\partial\tau}{\partial\gamma} > 0 \Leftrightarrow \alpha > \alpha''$ and $\frac{\partial\tau}{\partial\gamma} < 0 \Leftrightarrow \alpha < \alpha''$. If $d_1 > E[d]$, $\alpha < \alpha''$ is always fulfilled. Thus, if $d_1 > E[d]$, then $\frac{\partial\tau}{\partial\gamma} < 0$.

# C Proof Proposition 2

Let:

$$\bar{\gamma} \equiv 2 - \gamma - \gamma^2$$
$$\text{and } \bar{\chi} \equiv \chi + (1-\chi)E[d].$$

The profit of firm $i \in \{1,2\}$ (with $j \in \{1,2\}$ and $i \neq j$) is

$$\begin{aligned}
\Pi_i(\rho_i,\rho_j) =& \rho_i\rho_j\frac{1}{1-\gamma^2}\left(\frac{v\bar{\gamma}}{4-\gamma^2}\right)^2 + \rho_i(1-\rho_j)\frac{1}{1-\gamma^2}\left(\frac{v\bar{\gamma}+\gamma\bar{\chi}}{4-\gamma^2}\right)^2 \\
&+ (1-\rho_i)\rho_j\frac{1}{1-\gamma^2}\left(\frac{v\bar{\gamma}-(2-\gamma^2)\bar{\chi}}{4-\gamma^2}\right)^2 \\
&+ (1-\rho_i)(1-\rho_j)\frac{1}{1-\gamma^2}\left(\frac{v\bar{\gamma}-\alpha\bar{\gamma}\bar{\chi}}{4-\gamma^2}\right)^2 - c\rho_i^2.
\end{aligned}$$

Firm $i$ chooses $\rho_i$ to maximize its profit. As

$$\begin{aligned}
\frac{\partial\Pi_i(\rho_i,\rho_j)}{\partial\rho_i} = \frac{1}{1-\gamma^2}\frac{1}{(4-\gamma^2)^2}\Big(&\rho_j\left(v\bar{\gamma}\right)^2 + (1-\rho_j)\left(v\bar{\gamma}+\gamma\bar{\chi}\right)^2 \\
&- \rho_j\left(v\bar{\gamma}-(2-\gamma^2)\bar{\chi}\right)^2 - (1-\rho_j)\left(v\bar{\gamma}-\alpha\bar{\gamma}\bar{\chi}\right)^2\Big) - 2c\rho_i,
\end{aligned}$$

the best reply is either

$$\begin{aligned}
\rho_i(\rho_j) = \frac{\bar{\chi}}{2c(1-\gamma^2)(4-\gamma^2)^2}\Big(&2v\bar{\gamma}(\gamma+\alpha\bar{\gamma}) + \bar{\chi}(\gamma^2-\alpha^2\bar{\gamma}^2) \\
&+ \rho_j\Big(\bar{\gamma}^2(2v(1-\alpha)+\alpha^2\bar{\chi}) - \bar{\chi}(\gamma^2+(2-\gamma^2)^2)\Big)\Big),
\end{aligned}$$

or, as $\rho_i \in [0,1]$, a boundary solution. Let

$$\bar{v} \equiv \frac{\bar{\chi}^2(2-\gamma^2)^2 + 2c(1-\gamma^2)(4-\gamma^2)^2}{2\bar{\gamma}\bar{\chi}(2-\gamma^2)}.$$

It is straightforward to show, that in equilibrium

$$\rho_i^* = \frac{2v\bar{\chi}\bar{\gamma}\Big(\gamma+\alpha\bar{\gamma}\Big) + \bar{\chi}^2\Big(\gamma^2-\alpha^2\bar{\gamma}^2\Big)}{2c(1-\gamma^2)(4-\gamma^2)^2 - \bar{\chi}\bar{\gamma}^2\Big(2v(1-\alpha)+\alpha^2\bar{\chi}\Big) + \bar{\chi}^2\Big(\gamma^2+(2-\gamma^2)^2\Big)} \text{ if } v \leq \bar{v}$$

or

$$\rho_i^* = 1 \text{ if } v \geq \bar{v}.$$

# D The effects of $\alpha$, $\chi$, and $\gamma$ on the investments

Let

$$\begin{aligned}
\bar{\chi} &\equiv \chi + (1-\chi)E[d], \\
\bar{\gamma} &\equiv 2 - \gamma - \gamma^2, \\
\bar{v} &\equiv \frac{\bar{\chi}^2(2-\gamma^2)^2 + 2c(1-\gamma^2)(4-\gamma^2)^2}{2(2-\gamma-\gamma^2)\bar{\chi}(2-\gamma^2)}.
\end{aligned}$$

In the subgame-perfect Nash equilibrium, for all $i \in \{1, 2\}$:

(i) $\rho_i^* = 1$ if $v \geq \bar{v}$

(ii) $\rho_i^* = \frac{2v\bar{\chi}\bar{\gamma}\left(\gamma+\alpha\bar{\gamma}\right)+\bar{\chi}^2\left(\gamma^2-\alpha^2\bar{\gamma}^2\right)}{2c(1-\gamma^2)(4-\gamma^2)^2-\bar{\chi}\bar{\gamma}^2\left(2v(1-\alpha)+\alpha^2\bar{\chi}\right)+\bar{\chi}^2\left(\gamma^2+(2-\gamma^2)^2\right)}$ if $v \leq \bar{v}$.

**The effects of $\alpha$ on the investments**

If $v \geq \bar{v}$:

$$\frac{\partial \rho_i^*}{\partial \alpha} = 0.$$

If $v < \bar{v}$:

$$\begin{aligned}
&\frac{\partial \rho_i^*}{\partial \alpha} > 0 \\
\Leftrightarrow\ & \frac{2c(1-\gamma^2)(4-\gamma^2)^2 - \bar{\chi}\bar{\gamma}^2\left(2v(1-\alpha)+\alpha^2\bar{\chi}\right) + \bar{\chi}^2\left(\gamma^2+(2-\gamma^2)^2\right)}{\left[2c(1-\gamma^2)(4-\gamma^2)^2 - \bar{\chi}\bar{\gamma}^2\left(2v(1-\alpha)+\alpha^2\bar{\chi}\right) + \bar{\chi}^2\left(\gamma^2+(2-\gamma^2)^2\right)\right]^2} \\
& \times \left[2v\bar{\chi}\bar{\gamma}^2 - 2\alpha\bar{\chi}^2\bar{\gamma}^2\right] \\
& - \frac{\left[2v\bar{\chi}\bar{\gamma}\left(\gamma+\alpha\bar{\gamma}\right) + \bar{\chi}^2\left(\gamma^2-\alpha^2\bar{\gamma}^2\right)\right]\left[2v\bar{\chi}\bar{\gamma}^2 - 2\alpha\bar{\chi}^2\bar{\gamma}^2\right]}{\left[2c(1-\gamma^2)(4-\gamma^2)^2 - \bar{\chi}\bar{\gamma}^2\left(2v(1-\alpha)+\alpha^2\bar{\chi}\right) + \bar{\chi}^2\left(\gamma^2+(2-\gamma^2)^2\right)\right]^2} > 0 \\
\Leftrightarrow\ & (v-\alpha\bar{\chi})\left(2c(1-\gamma^2)(4-\gamma^2)^2 - 2v\bar{\chi}\bar{\gamma}^2 + \bar{\chi}^2(2-\gamma^2)^2 - 2v\bar{\chi}\bar{\gamma}\gamma\right) > 0.
\end{aligned}$$

As $v > 2/(1-\gamma) > 1 > \alpha\bar{\chi}$ and

$$2c(1-\gamma^2)(4-\gamma^2)^2 - 2v\bar{\chi}\bar{\gamma}^2 + \bar{x}^2(2-\gamma^2)^2 - 2v\bar{\chi}\bar{\gamma}\gamma > 0 \Leftrightarrow v < \bar{v},$$

$(\partial \rho_i^*)/(\partial \alpha) > 0$.

**The effects of $\chi$ on the investments**

If $v \geq \bar{v}$:

$$\frac{\partial \rho_i^*}{\partial \chi} = 0.$$

If $v < \bar{v}$:

$$\begin{aligned}
&\frac{\partial \rho_i^*}{\partial \chi} > 0 \\
\Leftrightarrow\ & \frac{2c(1-\gamma^2)(4-\gamma^2)^2 - \bar{\chi}\bar{\gamma}^2\Big(2v(1-\alpha)+\alpha^2\bar{\chi}\Big) + \bar{\chi}^2\Big(\gamma^2+(2-\gamma^2)^2\Big)}{\Big[2c(1-\gamma^2)(4-\gamma^2)^2 - \bar{\chi}\bar{\gamma}^2\Big(2v(1-\alpha)+\alpha^2\bar{\chi}\Big) + \bar{\chi}^2\Big(\gamma^2+(2-\gamma^2)^2\Big)\Big]^2} \\
&\times \Big[2v\bar{\gamma} + 2\bar{\chi}(\gamma - \alpha\bar{\gamma})\Big](\gamma+\alpha\bar{\gamma})(1-E[d]) \\
-&\frac{\Big[2v\bar{\chi}\bar{\gamma} + \bar{\chi}^2\Big(\gamma-\alpha\bar{\gamma}\Big)\Big]\Big(\gamma+\alpha\bar{\gamma}\Big)(1-E[d])}{\Big[2c(1-\gamma^2)(4-\gamma^2)^2 - \bar{\chi}\bar{\gamma}^2\Big(2v(1-\alpha)+\alpha^2\bar{\chi}\Big) + \bar{\chi}^2\Big(\gamma^2+(2-\gamma^2)^2\Big)\Big]^2} \\
&\times \Big[-2v\bar{\gamma}^2(1-\alpha) - 2\alpha^2\bar{\chi}\bar{\gamma}^2 + 2\bar{\chi}(\gamma^2+(2-\gamma^2)^2)\Big] > 0 \\
\Leftrightarrow\ & 2v\bar{\gamma}\Big[2c(1-\gamma^2)(4-\gamma^2)^2 - \bar{\chi}^2(2-\gamma^2)(2-\gamma^2+\gamma-\alpha\bar{\gamma})\Big] \\
&> 4c\bar{\chi}(1-\gamma^2)(4-\gamma^2)^2(\alpha\bar{\gamma}-\gamma). \qquad (15)
\end{aligned}$$

The left hand side of (15) is positive if

$$c > \frac{\bar{\chi}^2(2-\gamma^2)(2-\gamma^2+\gamma-\alpha\bar{\gamma})}{2(1-\gamma^2)(4-\gamma^2)^2} \equiv \bar{c}.$$

But $c > \bar{c}$ is always fulfilled, because the interior solution of $\rho_i^*$ only exists if

$$\bar{v} > v > \frac{2}{1-\gamma}$$

and for this range of $v$ to exist

$$\bar{v} > \frac{2}{1-\gamma} \Leftrightarrow c > \frac{4(2-\gamma^2)(2+\gamma)\bar{\chi} - \bar{\chi}^2(2-\gamma^2)^2}{2(1-\gamma^2)(4-\gamma^2)^2} > \bar{c}.$$

Consequently, the left hand side of (15) is always positive.

In contrast, the right hand side of (15) is positive if $\alpha\bar{\gamma} \geq \gamma$ and is negative if $\alpha\bar{\gamma} < \gamma$. Consequently, if $\alpha\bar{\gamma} < \gamma$, the right hand side is negative, which means $(\partial\rho_i^*)/(\partial\chi) > 0$.

If $\alpha\bar{\gamma} \geq \gamma$,

$$\begin{aligned}
&\frac{\partial \rho_i^*}{\partial \chi} > 0 \\
\Leftrightarrow\ & v > \frac{4c\bar{\chi}(1-\gamma^2)(4-\gamma^2)^2(\alpha\bar{\gamma}-\gamma)}{2\bar{\gamma}\Big[2c(1-\gamma^2)(4-\gamma^2)^2 - \bar{\chi}^2(2-\gamma^2)(2-\gamma^2+\gamma-\alpha\bar{\gamma})\Big]}.
\end{aligned}$$

Yet, as $v > 2/(1-\gamma)$ and

$$\bar{v} > \frac{2}{1-\gamma} \Leftrightarrow c > \frac{4(2-\gamma^2)(2+\gamma)\bar{\chi} - \bar{\chi}^2(2-\gamma^2)^2}{2(1-\gamma^2)(4-\gamma^2)^2},$$

this is always fulfilled. In sum, if $v < \bar{v}$, $(\partial\rho_i^*)/(\partial\chi) > 0$.

**The effects of $\gamma$ on the investments**

Let

$$\begin{aligned}
m \equiv& 2\bar{\chi}^2\bar{\gamma}\Big(2c\bar{\gamma}(2-\gamma)(2+\gamma)^2(1-\gamma+\gamma^2) - v\bar{\chi}\bar{\gamma}(2+\gamma^2) + \bar{\chi}^2(4-\gamma^4)\Big) \\
n \equiv& 4c\bar{\chi}\Big(v\bar{\gamma}^2(2-\gamma)(4+2\gamma+4\gamma^2+3\gamma^3) + \bar{\chi}\gamma(16-9\gamma^4+2\gamma^6)\Big) \\
&- 2(2+\gamma^2)\bar{\chi}^2\Big(v\bar{\gamma}^2 + \bar{\chi}\gamma(2-\gamma^2)\Big)(2v-\bar{\chi}).
\end{aligned}$$

If $v \geq \bar{v}$:

$$\frac{\partial \rho_i^*}{\partial \gamma} = 0.$$

If $v < \bar{v}$:

$$\begin{aligned}
\frac{\partial \rho_i^*}{\partial \gamma} > 0 &\Leftrightarrow \alpha^2 m - 2\alpha\frac{v}{\bar{\chi}}m + n > 0 \\
&\Leftrightarrow \Big(\alpha - \frac{v}{\bar{\chi}}\Big)^2 > \underbrace{\frac{v^2}{\bar{\chi}^2} - \frac{n}{m}}_{>0} \\
&\Leftrightarrow \alpha > \alpha_1 \equiv \frac{v}{\bar{\chi}} + \sqrt{\frac{v^2}{\bar{\chi}^2} - \frac{n}{m}} \\
&\qquad \text{or} \\
&\qquad \alpha < \alpha_2 \equiv \frac{v}{\bar{\chi}} - \sqrt{\frac{v^2}{\bar{\chi}^2} - \frac{n}{m}}.
\end{aligned}$$

As $v > 2/(1-\gamma) > 1 > \bar{\chi}$ and $\sqrt{v^2/(\bar{\chi}^2) - n/m} > 0$, $\alpha_1 > 1$. Therefore, $(\partial\rho_i^*)/(\partial\gamma) > 0$ if and only if $\alpha < \alpha_2$ and, in contrast, $(\partial\rho_i^*)/(\partial\gamma) < 0$ if and only if $\alpha > \alpha_2$. Note that

$0 \leq \alpha_2 \leq 1$ is not always fulfilled.

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