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Abstract. We examine the problem faced by a buyer seeking to purchase an experience good without prior knowledge of its stochastic quality. An expert who owns the product can be paid to provide a signal about its quality. Our analysis explores the impact of introducing a credible signaling mechanism for the buyer. Specifically, we propose using blockchain technology, which ensures immutability, decentralization, privacy, and transparency, to store the signal. Our findings reveal that this approach reduces the number of possible equilibria while preserving the "good equilibrium", in which information is both acquired and accurately transmitted. Consequently, the use of blockchain technology mitigates the equilibrium coordination problem and improves the provision of credible information.

1 Introduction

Availability of correct information is one of the central aspects in economic interaction. In his seminal paper, (Akerlof, 1970) demonstrates in a simple model for the market for lemons that asymmetric information leads to market failure. In essence, two agents want to trade a product, but the buyer does not have sufficiently accurate information on the product quality, and hence on personal utilities.

The analysis of trade under asymmetric information is at the heart of contract theory which aims at designing mechanisms that incentivize agents to reveal their private information through taking specific observable actions. For example, signaling mechanisms, as introduced by Spence (1973), allow the informed agent to send a message or signal to the uninformed one. Although it cannot be verified directly that the agent submits the credible signal, signaling costs are set up in a way that it is in the agent's best interest not to misrepresent information. In practice, therefore, costless signals only provide limited advice to potential buyers, e.g., (online) rating systems that are almost costless to use (Dellarocas, 2003). Similarly, the problem of limited informativeness occurs when the costs of a signal (e.g. a rating) is either independent from the signal itself or information on the signal costs cannot credibly be shared. As a result, signaling games typically show a large number of (separating and pooling) equilibria.[1]

[1] For our context, Fudenberg and Tirole (1988) show that the notions of Perfect Bayesian Equilibrium and Sequential Equilibrium are equivalent and P. Bolton and Dewatripont (2004, p. 103). state: "In signaling games, the difficulty is not to find a PBE. Rather the problem is that there are too many PBEs.

As an illustration of this problem we return to (online) rating systems that are supposed to inform potential buyers about the quality of a product. Typically, the costs of releasing a rating are low and not connected to the product quality so that we observe more and more the emergence of fake reviews (He et al., 2022) jeopardizing its original intent (Tadelis, 2016). From a technical perspective Mohawesh et al. (2021) survey the possibilities of detecting fake reviews by analyzing review texts. However, such methods are designed for detection, not prevention.

From a general perspective, a part of the problem is that information (e.g., on product quality) and action (e.g., give a rating) are decoupled. A device like blockchain[2] provides an interesting possibility to link both, information and action, by storing actions (in particular payments revealing information on incentives) in a way that this information is traceable, public, immutable, and a trusted third party is not required as intermediary (Franke et al., 2024). Moreover, acquisition of information stored in the blockchain can be designed costly, so that it is part of a buyer's strategic choice to acquire a signal or not (Yu et al., 2023; Zhang et al., 2024).

In this paper, we want to investigate, whether the blockchain technology (BCT) can be used to reduce information asymmetries in economic transactions. More precisely, we employ a simple model in which a buyer wants to buy a product of unknown quality. Assuming that the good is an experience good, its true quality cannot be observed prior to purchase. However, the buyer may receive information from another agent, named expert[3], who has already bought the product and therefore is informed about the true product quality. In a “traditional modeling”, the buyer may pay the expert for a quality assessment, and then base his[4] buying decision on the expert's signal. In this model, the expert's costs of providing any signal are independent of the signal. As we will demonstrate later (Proposition 1), the corresponding two-person game exhibits multiple sequential equilibria in pure strategies, so that a severe coordination problem occurs.

We compare the results with those in a model, in which the blockchain technology is avail- able. More precisely, the seller, who is not modeled as an active agent, allows the expert to buy the product either at regular or at discounted price.[5] The expert decides which price to pay for the purchase after experiencing the product quality, and that payment is stored in a blockchain. Therefore, the signal that she sends has a direct impact on her overall payoff. Phrased differently, the cost of a signal depends on the signal. Instead of “just asking” the expert about the product quality, the buyer now

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[2] This technology emerged from previous research on digital signatures Rivest et al. (2001), the Merkle tree by Merkle (1980), cryptographically secure time-stamping with blocks Haber and Stornetta (1991), and the precursors of digital money, see Back (2002); Dai (1998). Beyond its use as an infrastructure for cryptocurrencies, such as bitcoin, built-in features in the blockchain technology include immutability, decentralization, privacy and transparency, and distributed trust Filippi (2016); Nakamoto (2008); Seidel (2018); Swan (2015).

[3] Here, the term “expert” refers to an agent, who has already bought the product and has therefore experience with it and can assess its quality.

[4] Throughout this text, we use ’he’ and ’she’ to differentiate between two types of agents (expert - she, buyer - he). This choice of pronouns does not imply any gender-specific characteristics or biases regarding the individuals discussed.

[5] We may also think of the expert as the first buyer of the product.

has the possibility to pay for observing the stored transaction between the expert and the seller. In particular, signaling high quality (via paying regular price) now comes at a higher cost for the expert, thus increases her signal's credibility (Pornpitakpan, 2004).

The direct implication is that the existence of a device that stores immutable information, which is observable at a given cost, helps to reduce a coordination problem between an expert and an uninformed potential buyer. The “good equilibrium”, i.e., the expert always pays the price that matches the quality of the product, and the buyer acquires information, then perfectly correlates his buying decision on the signal, is still an equilibrium, however reachable with fewer coordination effort. In the game induced in the model with BCT, we show that there are fewer sequential equilibria compared to the game without BCT (Proposition 2).

As one application, a trading system with experts that are offered special purchase conditions can be designed to better inform buyers about product qualities. From an information economics perspective, such a system works because the cost of a signal becomes observable, and as a result signal credibility is enhanced. Many online platforms feature reputation systems to reduce uncertainty in transactions (Rice, 2012) and promote trust in sellers (Moreno & Terwiesch, 2014). The more reliable the implemented reputation mechanism is, the more it enhances trust in buying decisions (Honhon & Hyndman, 2020; Jøsang et al., 2007). Still, reputation systems are prone to strategic manipulation, especially due to false quality signals induced by low-quality sellers (G. E. Bolton et al., 2013; G. E. Bolton et al., 2004; Kennes & Schiff, 2007).

Implementing reputation systems on a blockchain is considered the most reliable way to store feedback information and exclude manipulation (Bellini et al., 2020; Cai & Zhu, 2016; Hawlitschek et al., 2018). A blockchain is a tamper-proof, chronological ledger implemented as a distributed database for transactions secured by cryptographic mechanisms and governed by a consensus protocol (Beck et al., 2017). A community of computing nodes produces a blockchain by exchanging and storing digital transactions that are recorded in blocks, building an ever-growing chain. Cryptographic mechanisms guarantee that transactions can be verified and any unauthorized change of transaction data is easy to detect. The consensus protocol provides economic incentives that ensure only valid transactions are stored in the blockchain. In a truly decentralized network, distributed consensus mechanisms provide an extraordinary degree of tamper- resistance, removing the necessity to include a trusted third party for checking transactions' legitimacy and authenticity (Nakamoto, 2008; Tschorsch & Scheuermann, 2016).

From the contract theory perspective, P. Bolton and Dewatripont (2004), Kreps and Sobel (1994), or Kőszegi (2014) provide extensive survey on how to incentivize agents to reveal private information. As one expects, there remains a trade-off between incentive compatibility and efficiency. Mamada (2022) follows an interesting approach to solve the market for lemons problem by considering signal indices already defined in Spence Spence (1973) that can costly be observed. For used cars this means that the state of air-conditioning can costly be verified, which is correlated with the quality of the car. He shows that if the price falls into a specific range, cars with bad air-conditioning are driven out of the market. Unlike in our approach, there has to be an opportunity to test the product prior to purchase.

Gersbach et al. (2022)) discuss a model with severallow and high quality sellers and one buyer, who potentially wants to buy more than one product. They set up a four stage mechanism, in which prices depend on the actions of all sellers and show that in equilibrium all high-quality sellers send a different signal than low-quality sellers. Compared to our work, we focus on the revelation of quality information through the interaction of (two) buyers.

In supply chain manufacturing, a blockchain can be used to store the quality of a product itself. In such models, information disclosure through BCT is a strategic choice and will only be used by high-quality sellers (Xu & He, 2023; Zhang et al., 2024). However, in our model, product quality is not verifiable prior to purchase and cannot credibly be shared, so that the agents are dependent on quality signals.

The paper is organized as follows: Section 2 introduces the two games with imperfect infor- mation without (Model 1) and with (Model 2) deploying a blockchain technology. While Section 3 briefly reviews the concept of sequential equilibria, the results are presented in Section 4. Section 5 concludes. All calculations of equilibria are relegated to the appendices.

2 Model

In this section, we set up two models describing the interaction between two buyers of the same product, the quality of which is unknown. More precisely, a seller offers one unit of a pro- duct at a given price $p > 0$ and delivers the product in either good or bad quality. We assume that the product is an experience good meaning that a buyer can only observe its quality after consumption, i.e., only after a purchase. The buyer's utility from consumption expressed as will- ingness to pay is $B > 0$, when the product quality is high, and 0 otherwise. In order to reduce information asymmetries, the buyer can retrieve information on the product quality from an ex- pert (or experienced buyer), who has already bought and assessed the same product. The expert's utility from consumption is either $r > 0$ or 0 given that the quality is high or low, respectively. Both, the expert and the buyer, have use for at most one unit of the product.

As we are primarily interested in mechanisms for information transmission from the expert to the buyer, we model the quality of the product as a chance move with the known priors q for high quality and *1 —* q for low quality. The expert and the buyer are assumed to be risk-neutral, and the seller is not modeled as an active decision-maker, so that product quality is not a strategic choice. To eliminate the effects of long-term reputation, we think of a one-shot interaction taking place anonymously, e.g., on an online platform.

In what follows, we introduce and compare two versions of the way in which information can be transmitted to the buyer. In both models, the sequence of actions is described as a sequential move game with imperfect information. First the expert buys the product and is therefore perfectly informed about the realization of the chance move. While the expert knows the pro- duct quality, the buyer has no information about it. However, he knows that the expert observed the quality. This asymmetric information environment is the key feature in our models. Before buying the product the buyer may acquire a signal about the product quality from the expert. The difference between the models lies in how information is signaled and how the signals are designed.

In both models, there is an incentive for the expert to report truthfully. While in the first model the buyer has to completely rely on the expert's signal, in the second model we use BCT to store the expert's signal, i.e., the real payment. With blockchain, the signal is confirmed and can be retrieved by the buyer. The goal of the analysis is to investigate how the set of equilibria changes when the blockchain is employed.

Model 1: Reported Quality

Figure 1 illustrates the game tree in Model 1. The game starts with a chance move with pro- babilities q and *1 —* q choosing high or low quality, respectively. We assume that the expert then buys the product at price p and directly assesses its quality, i.e., she observes the outcome of the chance move. Depending on whether the true quality is high or low, the expert makes a decision on which quality level to report to the buyer when asked.[6] More precisely, given the true quality is “high” (“low”), the expert either chooses *H+ or L+ (H- or L-)* to signal high or low quality.[7]

From now on, all remaining decisions are taken by the uninformed buyer. He first has the option to acquire *(ac)* information from the expert by paying her an amount $x > 0$ or refuse (*ref*) to do so. After that, he takes a final decision on buying or not buying the product. Formally, he chooses an action buy^{+},buy^{-}, or buy^{0} for buying the product, after receiving a signal of *high quality*, *low quality*, or *no signal on quality*, respectively. Similarly, the actions nb^{+}, nb^{-}, or nb^{0} refer to not buying the

[6] To have a greater similarity of the game trees of the two models, this decision is modeled prior to the buyer's decision whether or not to acquire information from the expert.

[7] While *H* and *L* refer to the experts action, the superscript “+” (“—”) means that the true quality is “high” (“low”).

product.[8] Due to the unobservability of the chance move and possibly unacquired information, the buyer has four information sets, displayed in different colors.

At each terminal node, the payoffs for expert (top line) and buyer (bottom line) are displayed. They are determined as follows: Independent of the product quality, the expert pays the price p. Her net utility is $v - p$ when the realization of the chance move is high, and $0 - p$ otherwise. If the buyer buys the product, he pays the same price p. In case the bought product is of high quality, he receives u, and 0 for a low quality product. If he does not buy the product, his utility is 0. Whenever the buyer chooses *ac* and therefore the expert sends a quality signal, a fee $x > 0$ is transferred from the buyer to the expert.

So far, the expert is not provided with incentives to tell the truth, because the fee x she may receive is independent of the signal she gives. In addition, the expert receives a bonus $r > 0$ paid by the platform, when the buyer bought the product and the report was truthful. We may think of the buyer approving or not the acquired information, but do not model it as an explicit action.[9] The platform (owner) is not explicitly modeled as an agent. As the platform is interested in having a working system that allows buyers to acquire information from the expert and receive a correct response, there is good reason to pay the bonus r. From a far-sighted perspective, such a possibility can attract future buyers to use the platform.

In sum, the payoffs depend on the utility received from a high quality product (u or r), the price of the product p, and possibly on the fee x and bonus r. The following assumptions capture specific scenarios for which we will analyze equilibria in the next section.

[8] Here superscripts do not refer to the true quality of the product but to the information provided ("+" for "high" signal, "—" for "low" signal) or not provided ("0" for no signal) by the expert.

[9] As the game is over after the approval, it is not necessary to incentivize the buyer to tell the truth here.

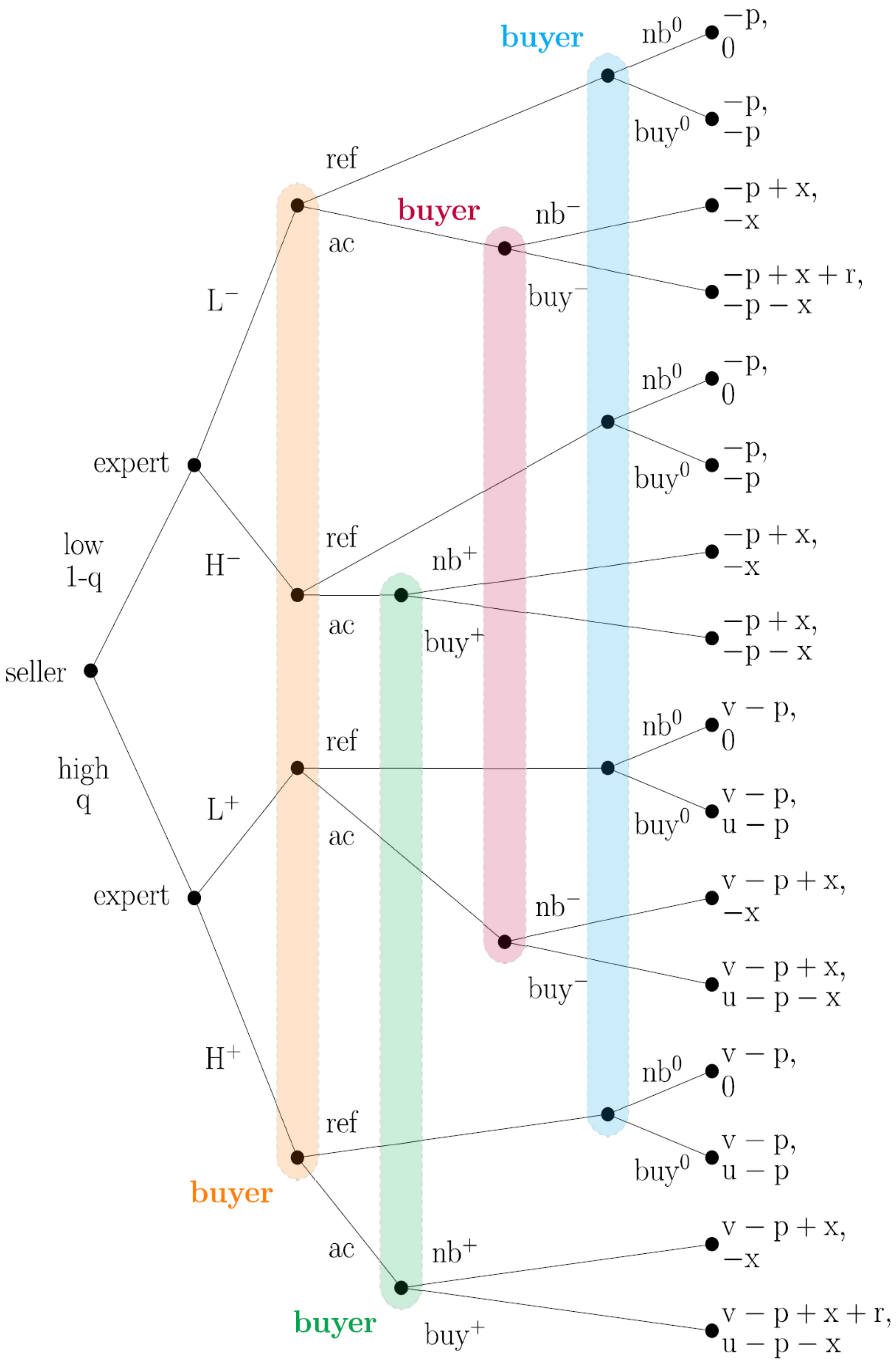

Figure 1: Game Tree in Model 1: Quality Reported

Al $uq - p > 0$ and $vq - p > 0$

Al' $uq - p < 0$ and $vq - p > 0$

A2 $(1 - q)p > x$

A2' $q(u - p) > x$

Assumptions *A1* and *A1'* are mutually exclusive. *A1* guarantees that the expected utility from buying the product exceeds the price for the buyer. It can be viewed as a participation constraint and implies that a completely uninformed, risk-neutral buyer does buy the product.[10] In contrast, assumption *A1'* requires the buyer not buy the product, when he is uninformed. In either assumption *A1* and *A1'*, the buyer expects to have a positive net utility from buying the product $(u - p > 0)$.

Assumptions *A2* and *A2'* relate the fee x to the buyer's expected net utility or net loss. As- sumption *A2* can be rewritten to $q(u - p) + (1 - q)(0 - p) < q(u - p) - x$, which means that the expected utility from buying the product without information is lower compared to having the correct signal at cost x. Phrased differently, it ensures that paying the fee is better than receiving a low quality product. Otherwise, there would be no incentives to ask an expert. Assumption *A2'* ensures that the fee is smaller than the expected utility gain, so that paying x is overcompen- sated by receiving a high quality product. Interestingly, when subtracting the 1.h.s. in *A2* from the 1.h.s. in *A2'* we get $q(u - p) - (1 - q)p = qu - p$ which is positive (negative) under *A1 (A1')*. A direct implication is given in the following lemma.

Lemma 1. *Assumption A1 and A2 together imply A2'. Assumptions A1' and A2' jointly imply A2.*

In essence the key characteristic of Model 1 lies in the fact that the buyer can choose to base his buying decision on information that cannot credibly be transmitted from the expert to the buyer, as he cannot learn the result of the chance move without buying the product.

Model 2: Information access via Blockchain

The game tree in Model 2 is depicted in Fig. 2. What changes is the type of signal from the expert and the access to information. We now assume that a two-price contract is

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[10] Technically, it implies that the action buy^0 dominates the action nb^0 in the corresponding (blue) information set.

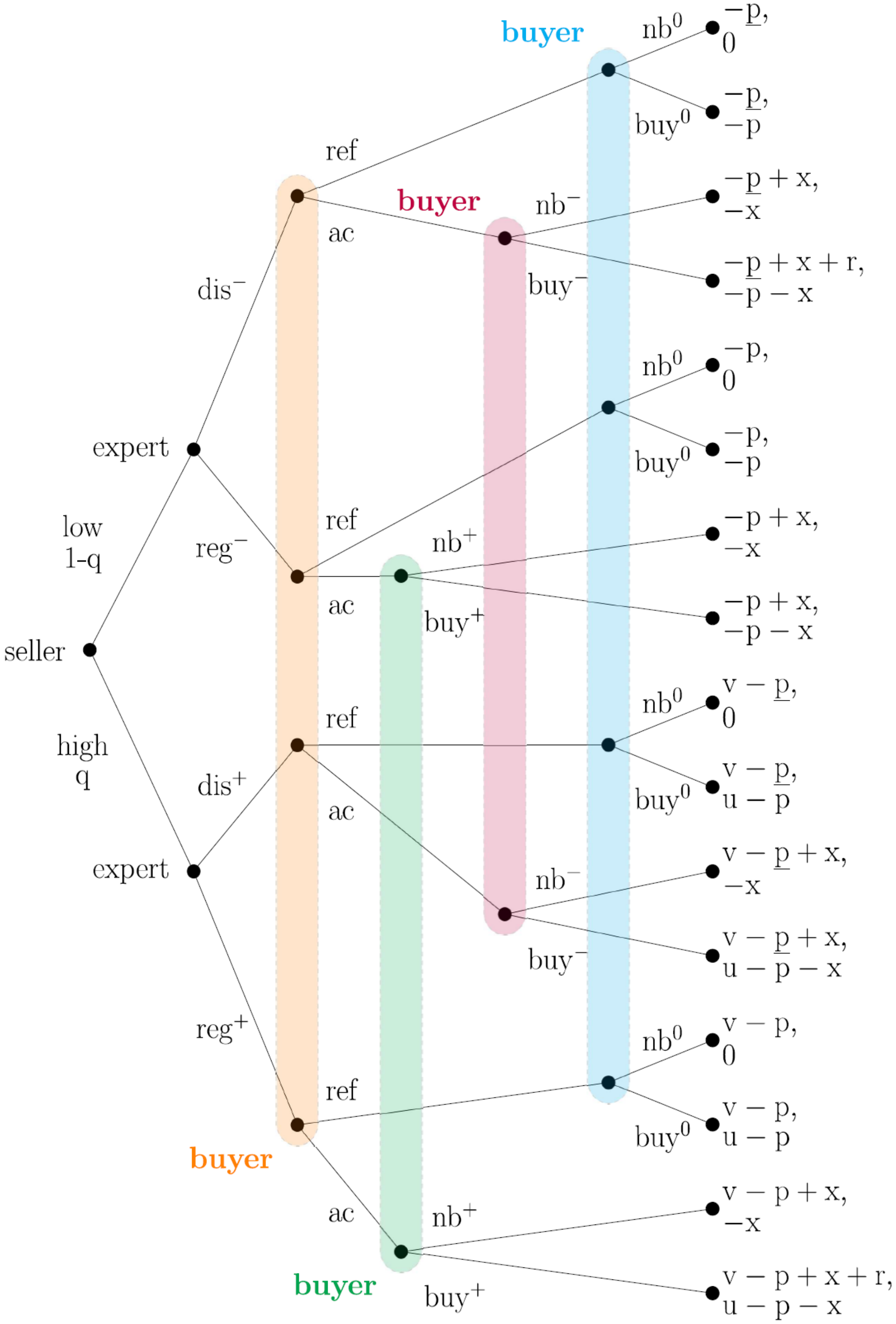

Figure 2: Game Tree in Model 2: Information Access via Blockchain

offered from the seller to the expert. That means, she buys the product, assesses its quality, and can then either pay the regular price p (action *reg*) or a specified discounted amount $\underline{p} < p$ (action *dis*). The final payment to the seller is stored in a blockchain so that it cannot be modified anymore and can be retrieved from a third party. This stored information is used as the signaling feature of the model. The difference to Model 1 is that the price paid by the expert serves as the signal. Hence, signaling high quality by paying the regular price instead of a discounted one comes at a cost for the expert. This is in line with the general idea of signaling information in economics. The more costly a signal is, the more credible it is (Pornpitakpan, 2004). In this model, signaling the high quality by paying the higher price preserves the chance of receiving the bonus payment r at the end.

The buyer chooses to acquire information (action *ac*) or not (action *ref*) from the blockchain at a fee x paid to the expert. In the former case, he knows whether the expert made the regular or the discounted payment. A regular payment (discounted payment) of p $(\underline{p})$ is supposed to signal high (low) quality. But information on payment can credibly be obtained thanks to the use of a blockchain.

The sequence of the buyer's actions is identical to the first model, so we keep the same notation for actions and payoffs. The main difference in the payoffs is that the expert can choose to pay either p or $\underline{p}$. Again, at the very end the expert may receive a bonus r, if the buyer acquired information, bought the product, and approved accuracy of the signal.

Additional to Assumptions *A1-A2* (or *A1'-A2'*), it is instructive to introduce the following intuitive assumption on the bonus payment r:

A3 $r > p - p$.

Assumption *A3* guarantees that it is more attractive to pay the regular price and receive the bonus r than to pay the discounted price. Otherwise, the expert has no incentive to pay the regular price p.

3 Strategic Behavior

To economize on notation, the expert and the buyer are also denoted as agent 1 and 2, respectively. A *pure strategy* for agent i (i=1,2) is a mapping that takes each of agent *i's* information sets to one of the feasible actions therein. In Model 1, we can therefore describe the expert's possible pure strategies by $S^{1,1} := \{H^+, L^+\} \times \{H^-, L^-\}$. In Model 2, her pure strategies are given by $S^{2,1} := \{reg^+, dis^+\} \times \{reg^-, dis^-\}$. The set of the buyer's pure strategies is the same in both models and given by $S^2 = S^{1,21} = S^{2,2} := \{ac, ref\} \times (buy^+, nb^+\} \times (buy^-, nb^-\} \times (buy^0, nb^0\}$.

We analyze agents' strategic behaviors by inspecting the extensive form games with imperfect information as described in Model 1 and 2. From a static viewpoint, the agents choose their plans of action prior to the game and the game play results from execution of these plans. In the normal-form game the strategy sets are the pure strategies as above and payoffs at a strategy profile are formed by following the path that is visited by the application of the actions in the strategy profile. This way we can identify Nash equilibria (NE) of the normal-form game. However, this static view neither takes the sequentiality of decisions nor imperfect information into account. More- over, the number of Nash equilibria is typically large, so a refinement of the Nash equilibrium concept strengthens the predictive power and typically reduces the number of equilibria. Yet, as both versions of the game (from the two models) admit only a single subgame, the subgame perfect equilibrium concept has no further bite compared to Nash equilibria (of the normal-form game). We therefore discuss the concept of sequential equilibria introduced by Kreps and Wilson (1982) next.

A *behavioral strategy* b_i *for agent i* specifies a probability distribution over the feasible actions in each information set, in which agent *i* chooses. A pure strategy of agent i is a special behavioral strategy, which assigns in each information set a probability of 1 to the action chosen in the pure strategy (and hence 0 to all other actions). A behavioral strategy of agent *i* is *completely mixed* if it assigns a positive probability to each of the feasible actions in each of an agent's information set. A *belief* β_i|3; of agent *i* includes for each information set of that agent a probability distribution over the nodes included in the information set. A pair $\beta = (\beta_1, \beta_2)$ of beliefs for both agents is a belief system. A tuple (b, β) = $((b_1, b_2), (\beta_1, \beta_2))$ consisting of a profile of behavioral strategies and a belief system is termed an *assessment*. To define sequential equilibria we first discuss the following properties for an assessment (b, β).

Sequential Rationality Within each information set h_i of agent *i*, the probability distribution $b_i(h_i)$ over actions in h_i maximizes the agent's expected payoff given the belief $b_i(h_i)$ over nodes in that information set and the behavioral strategy profile *b*.

Bayesian Consistency The belief system $\beta = (\beta_1, \beta_2)$ is generated by the strategy profile via Bayesian updating. That means, given the probabilities in b = (b_1, b_2) to take actions, the belief of deciding at a specific node in information set h is the probability of reaching that node conditional on reaching some note in *h*.

Sequential rationality requires the agents choose behavioral strategies that maximize their payoffs given their beliefs about the node at which the decision has to be taken. Bayesian up- dating means that given the strategy choices, agents' beliefs are formed in a compatible way. However, it could happen that by the application of a behavioral strategy profile, an information set is not visited at all. In those information sets h, the belief formation via Bayesian updating is not possible. It means that a rationality condition based on Bayesian updating per se makes no sense, so that $b_i(h)$ cannot be identified as an optimal choice in h. For such cases, we need a more sophisticated form of consistency.

Consistency There exists a sequence (b^m, β^m) $m \in \mathbb{N}$ of assessments in which b^m is completely mixed and β^m is Bayesian consistent so that $lim_{m\to\infty}(b^m, \beta^m) = (b,\beta)$ holds.

Now, we are ready to define our equilibrium concept:

Sequential Equilibrium A *sequential equilibrium (SE)* is an assessment (b,β) which satisfies Sequential Rationality and Consistency.

If the behavioral strategies are such that all information sets in the game tree are reached with positive probability, Bayesian consistency and consistency coincide. Hence, consistency is trivially satisfied. Then in equilibrium, sequential rationality and Bayesian consistency ensure optimal decisions w.r.t. correct beliefs. If an information set h is reached with zero probability, belief formation according to Bayesian updating as well as rational choice is not possible. Nonetheless, the equilibrium action choice in h is rationalizable, if it maximizes the agent's payoff given plausible beliefs, i.e., beliefs $\beta^m m \in \mathbb{N}$ which are formed via behavioral strategies beliefs $(b^m) m \in \mathbb{N}$ being close to the equilibrium strategies b. Completely mixed strategies b^m for any $m \in \mathbb{N}$ guarantee that every information set is reached with positive probability, so that the plausible beliefs W stem from Bayesian updating.

When comparing sequential equilibria in the extensive form game with (pure) Nash equilibria of the normal-form game, it is easy to see that any sequential equilibrium is a Nash equilibrium, which is due to sequential rationality.[11] Conversely, not every Nash equilibrium needs to be a sequential one. Intuitively, a Nash equilibrium may include actions that are not sequentially rational in an information set as a "threat" to make the opponent stay away from a particular strategy choice and not reach that information set. Therefore, the sequential equilibrium concept is insensible to this form of non-credible threats. Roughly speaking, increasing the degree of rationality built in the equilibrium concept reduces the number of equilibria.

4 Results

The "desired" or "good" behavioral strategy is arguably the one in which the expert reports or pays according to the true quality, then the buyer acquires information and buys according to the signal he receives. The buying decision when no information is available is governed by Assumption *A1* (buy) or *A1'* (not buy). Let us denote this behavioral strategy by b^{des}. Besides the question, whether

[11] Sequential rationality means that deviating to another strategy reduces the payoff, as it is not optimal in one information set.

bde' is part of some sequential equilibrium (together with a consistent belief system) we are interested in finding out whether the use of BCT reduces information asymmetries. We use the following route to answer this second question: For the games in Model 1 and in Model 2, we compare the numbers (and sets) of sequential equilibria, i.e., investigate if employing the blockchain method helps to reduce coordination issues. Attaining uniqueness of the equilibrium in Model 2 is certainly to much to hope for, because the strategy profile, in which the expert never pays the regular price and the buyer does not acquire information, will always form a sequential equilibrium. The expert cannot improve her payoff, because she can never receive the bonus r and the buyer cannot be better off as the expert's strategy choice does not reveal any information. To compare numbers of equilibria, we restrict attention to pure sequential equilibria, as there are at most finitely many.[12] The sequential equilibrium concept is a refinement of the Nash equilibrium concept applied to the normal-form derived from the sequential move game(s). To start, there is a large number of pure Nash equilibria. The game in Model 1 has 10 pure Nash equilib- ria with 2 different equilibrium outcomes.[13] In Model 2 (with blockchain technology) we have 6 Nash equilibria in pure strategies, again with 2 different outcomes. For details see Table 1 and for the computation see Appendix A.

The following two propositions provide the results for Model 1 and Model 2. These results demonstrate that (a) moving to the sequential equilibrium dramatically reduces the number of equilibria and (b) the coordination problem simplifies through the use of BCT, because information can credibly be shared and actions (payment) are linked with the signal.[14] The Nash and sequential equilibria in Model 1 and 2 are displayed in Table 1, he proofs are relegated to the appendix.

[12] That means, each equilibrium satisfies the requirements of a sequential equilibrium from the previous section. In particular, there is no mixed sequential equilibrium that provides a greater payoff to some agent given the equilibrium beliefs.

[13] The outcome of an assessment is a probability distribution over the terminal nodes of the game tree.

[14] Technically,we identify actions in Model 1 with actions in Model 2 in the canonic way. Therefore, we get a bijection of strategies in the models that allows us to compare sets of equilibria.

Table 11: Sequential Equilibria of both Models under the Assumptions A1, A2, A3 or Al', A2', A3'

	Player 1		Player 2	NE		SE	
	Model 1	Model 2	Model 1 and 2	Model 1	Model 2	Model 1	Model 2
Under the assumptions $A1, A2$, and $A3$							
I (b^{des})	H^+L^-	reg^+dis^-	$ac\ buy^+nb^-buy^0$	✓	✓	✓	✓
II	H^+L^-	reg^+dis^-	$ac\ buy^+nb^-nb^0$	✓	✓	×	×
III	L^+L^-	dis^+dis^-	$ref\ buy^+buy^-buy^0$	✓	✓	✓	✓
IV	L^+L^-	dis^+dis^-	$ref\ nb^+buy^-buy^0$	✓	✓	✓	✓
V	L^+L^-	dis^+dis^-	$ref\ nb^+nb^-buy^0$	✓	✓	×	×
VI	L^+L^-	dis^+dis^-	$ref\ buy^+nb^-buy^0$	✓	✓	×	×
VII	H^+H^-	reg^+reg^-	$ref\ buy^+buy^-buy^0$	✓	×	✓	
VIII	H^+H^-	reg^+reg^-	$ref\ nb^+nb^-buy^0$	✓	×	×	
IX	H^+H^-	reg^+reg^-	$ref\ buy^+nb^-buy^0$	✓	×	✓	
X	H^+H^-	reg^+reg^-	$ref\ nb^+buy^-buy^0$	✓	×	×	
Under the assumptions $A1', A2'$, and $A3$							
XI	H^+L^-	reg^+dis^-	$ac\ buy^+nb^-buy^0$	✓	✓	×	×
XII (b^{des})	H^+L^-	reg^+dis^-	$ac\ buy^+nb^-nb^0$	✓	✓	✓	✓
XIII	L^+L^-	dis^+dis^-	$ref\ buy^+buy^-nb^0$	✓	✓	×	×
XIV	L^+L^-	dis^+dis^-	$ref\ nb^+buy^-nb^0$	✓	✓	×	×
XV	L^+L^-	dis^+dis^-	$ref\ nb^+nb^-nb^0$	✓	✓	✓	✓
XVI	L^+L^-	dis^+dis^-	$ref\ buy^+nb^-nb^0$	✓	✓	✓	✓
XVII	H^+H^-	reg^+reg^-	$ref\ buy^+buy^-nb^0$	✓	×	×	
XVIII	H^+H^-	reg^+reg^-	$ref\ nb^+nb^-nb^0$	✓	×	✓	
XIX	H^+H^-	reg^+reg^-	$ref\ buy^+nb^-nb^0$	✓	×	×	
XX	H^+H^-	reg^+reg^-	$ref\ nb^+buy^-nb^0$	✓	×	✓	

Proposition 1 (Sequential equilibria without BCT).

1. Under Assumptions A1 and A2, there are 5 sequential equilibria in pure strategies of the game in Model 1 given my E^1 —— {I, III, IV, VII, IX}.

2. Under Assumptions A1' and A2', there are 5 sequential equilibria in pure strategies of the game in Model 1 given by $E^{1'}$ = {XII, XV, XVI, XVII, XX}.

3. Under either set of assumptions, A1 and A2 or A1' and A2', there is a belief system β^{des} such that (b^{des}, β^{des}) is a sequential equilibrium.

Proposition 2 (Sequential equilibria with BCT).

1. Under Assumptions A1, A2, and A3, there are 3 sequential equilibria in pure strategies of the game in Model 2 given by the set E^2 = {I, III, IV}. further, $E^2 \subset E^2$.

2. Under Assumptions A1', A2', and A3, there are 3 sequential equilibria in pure strategies of the game in Model 2 given by the set $E^{2'}$ = {XII, XV, XVI, XX}.

3. Under either set of assumptions, A1, A2, and A3 or A1', A2', and A3, there is a belief system β^{des}*such that* (b^{des}, β^{des}) *is a sequential equilibrium in the game of Model 2.*

The propositions show in particular that the desired strategy profile b^{des} is (a part of) a se- quential equilibrium in both Model 1 and Model 2. Recall that the two sets of assumptions reflect the cases, in which the buyer has a positive or negative expected utility from buying the product without any further knowledge.

A comparison of the propositions shows that the use of BCT used for information retrieval shrinks the set of equilibria. Interestingly, when we take a closer look at which equilibria drop out, it turns out that using BCT eliminates all equilibria, in which the expert reports high quality in case that the quality is low (in Model 1 there are such equilibria; see last two columns of Table 1). It follows that an (equilibrium) action of paying the discounted pice is an accurate signal for low quality when using BCT. This observation is independent of the buying incentives of an uninformed buyer.

The number of equilibria can, however, not be reduced to one. This is because the strategy, in which the expert always pays the discounted price and the buyer never acquires information is an "unavoidable" equilibrium strategy. But, the desired equilibrium strategy is payoff dominant (cf. Table A.2 and Table A.3), and this fact reconciles with the left over coordination problem in Model 2. Thus, also from this perspective, the desired equilibrium is desired by the two agents as a group.

5 Discussion

Our paper shows that storing quality signals in a blockchain with signal dependent costs reduces incentives for strategic lying between informed and uninformed agents, as verifiable payments serve as cost-backed quality signals. Due to its built-in features of immutability, decen- tralization, transparency, and distributed trust, BCT provides a reliable infrastructure for quality signals.

Our analysis is kept simple and limited to a one-shot interaction between two players. In other words, our model with anonymous agents does not accommodate considerations for reputational effects as they were studied in the seminal paper by Shapiro (1982). However, future endeavors could involve devising a repeated game setup wherein our models serve as the foundation for the stage game. Giving up anonymity of agents, in such a model we could explore in how far BCT helps to build up (long-term) reputation.

As an implication, the quality signal can leverage the design of superior reputation systems that base on BCT, improving data-sharing platforms (Hawlitschek et al., 2018) and collaboration platforms (Narang et al., 2019). Our approach builds on payments as reliable quality signals, in- centivizing buyers to reveal the real quality of a product. When a secure transaction environment is established, buyers might also sell their ratings to other market participants or exchange them for other ratings. Envisioning a scenario that allows buyers and sellers to trade quality signals (Hemmrich et al., 2023), our results may have a profound impact on how companies organize their relationships (Beck et al., 2017), do marketing (Herhausen et al., 2020), select sellers or buyers (Ekstrom et al., 2005; McKnight et al., 2017), and create social welfare (Arrow, 1950). Aligning the payoffs with acting honestly in an open system also allows the creation of trustfully generated digital information and assets without institutionallegitimacy, promoting digital rating representations of non-digital real-world objects (Pereira et al., 2019). These quality signals may reduce information asymmetries and help with selection problems starting with the market for lemons (Akerlof, 1970) up to data oracles (Caldarelli, 2020).

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Appendix A: Determination of Nash and Sequential Equilibria under A1 - A3

Appendix A provides the calculations and hence proofs of Propositions 1 and 2 under the assumptions A1, A2, and, whenever applicable, A3. In Appendix B we display the same analysis under assumptions A1', A2', and A3. Finally Appendix C treats the case Bq — p = 0, in which a completely uninformed buyer is indifferent between buying and not buying the product. Nash equilibria in the games of Models l and 2 Model 1 is informationally equivalent to the simultaneous move game in which the expert has the 4 strategies (H^+H^-), (H^+L^-), (L^+H^-), (L^+L^-) and the buyer's strategy set {ac, ref} × (buy^+, nb^+} × {buy^-, nb^-} × {buy^0, nb^0} has 16 members as he has 2 possible actions at each of his four informa- tion sets. Model 1's pure strategy Nash equilibria are found via the normal-form representation of that simultaneous move game. Those equilibria are readily determined by payoff comparisons and are shown in Table A.2. We reach the Nash equilibria in the game in Model 2 via similar argumentation (see Table A.3). Here the expert's strategies are (reg^+reg^-), (reg^+dis^-), (dis^+reg^-), (dis^+dis^-). The game in Model 1 has 10 Nash equilibria in pure strategies, while the game in Model 2 has 6 Nash equilibria.

Bayesian Consistency

Next, we will search for the sequential ones among those equilibria. We denote the expert and the buyer as Player 1 and 2, respectively. Let b_1,b_2 be their completely mixed behavioral strategies. The corresponding Bayesian consistent beliefs will be computed as follows: $\beta^1\ m \in \mathbb{R}^4$ represents the beliefs of Player 2 at the first information set from left (orange). β_1^1 is the belief that the decision node at the bottom is reached, i.e., the product quality is high and Player 1 has played H^+, while β_2^1 is the belief that the second decision node from bottom is reached, i.e., the product quality is high and Player 1 has played L^+. In case of the low quality product, Player 2 believes that Player 1 has played H^-L^- with probability β_3^1, β_4^1, respectively. Under the assumption that b_1,b_2 are completely mixed, the belief Q1 can be computed via conditional probability:

$$\beta^1 = (\beta_1^1, \beta_2^1, \beta_3^1, \beta_4^1) = (sq, (1-s)q, t(1-q), (1-q)(1-t)) \qquad (A.1)$$

Where s = b_1 (H^+), t = b_1 (H^-) represents the beliefs of the buyer at the second information set from left (green). When this information set is reached, Player 2 believes with probability β_1^2 that the decision node at the bottom is reached. Similarly, the belief β^2 can be computed via conditional probability:

$$\beta^2 = (\beta_1^2, \beta_2^2) = \left(\frac{sq}{sq + t(1-q)}, \frac{t(1-q)}{sq + t(1-q)}\right). \qquad (A.2)$$

$\beta^3 \in \mathbb{R}^2$ represents the beliefs of the buyer at the third information set from left (pink). Via similar argumentation, one can see that

$$\beta^3 = (\beta_1^3, \beta_2^3) = \left(\frac{q(1-s)}{q(1-s)+(1-q)(1-t)}, \frac{(1-q)(1-t)}{q(1-s)+(1-q)(1-t)}\right). \qquad (A.3)$$

The fourth information set of Player 2 is represented in blue. The belief vector of Player 2 for this information set is β^4, and the beliefs in reaching decision nodes from bottom to top are as follows:

$$\beta^4 = \left(\beta_1^4, \beta_2^4, \beta_3^4, \beta_4^4\right) = (sq, (1-s)q, t(1-q), (1-t)(1-q)). \qquad (A.4)$$

Sequential equilibria in the game of Model 1

For any Nash equilibria in Model 1, one can easily construct the equilibrium strategy as a behavioral strategy. Then, that behavioral strategy b along with a belief system β must satisfy Consistency and Sequential Rationality. To do so, for any h, we must find a β, so that together they satisfy Sequential Rationality. Then, a sequence of assessments (b^m, β^m) $m \in \mathbb{N}$ of completely mixed b^m, Bayesian consistent β^m converging to b, β is necessary. If an equilibrium is not sequential, it will be justified here why this is the case. Below in Table A.4, one can see that 5 out of 10 Nash equilibria in Model 1 are sequential equilibria. The corresponding belief systems and the assessment sequences that allow us to confirm sequential rationality and consistency are shown in Table A.5.

It remains to show that the other Nash equilibria are not sequential equilibria. We show this separately.

- **Equilibrium II:** For any $b_1^m(H^+), b_1^m(H^-) \in (0,1)$, $\mathbb{E}_2[\text{buy}^0] > \mathbb{E}_2[\text{nb}^0]$ as $\mathbb{E}_2[\text{buy}^0] = (u-p)\beta_1^4 + (u-p)\beta_2^4 + (-p)\beta_3^4 + (-p)\beta_4^4 = (u-p)q - p(1-q) = uq - p > 0 = \mathbb{E}_2[\text{nb}^0]$. By sequential rationality, this equilibrium cannot be a sequential equilibrium.

Table A.2: The Normal-Form Representaticon of Model 1 in which the Players' Best Responses are Marked

Buyer (Player 2)	Expert (Player 1): H^+H^-		H^+L^-		L^+H^-		L^+L^-	
$ac\ buy^+buy^-buy^0$	$uq-p-x$	$(v+r)q-p+x$	$uq-p-x$	$vq-p+x+r$	$uq-p-x$	$vq-p+x$	$uq-p-x$	$(v+r)q-p+x$
$ac\ buy^+nb^-buy^0$	$uq-p-x$	$(v+r)q-p+x$	$(u-p)q-x$	$(v+r)q-p+x$	$pq-p-x$	$vq-p+x$	$-x$	$vq-p+x$
$ac\ buy^+buy^-nb^0$	$uq-p-x$	$(v+r)q-p+x$	$uq-p-x$	$vq-p+x+r$	$uq-p-x$	$vq-p+x$	$uq-p-x$	$(v+r)q-p+x$
$ac\ buy^+nb^-nb^0$	$uq-p-x$	$(v+r)q-p+x$	$(u-p)q-x$	$(v+r)q-p+x$	$pq-p-x$	$vq-p+x$	$-x$	$vq-p+x$
$ac\ nb^+buy^-buy^0$	$-x$	$vq-p+x$	$pq-p-x$	$(v+r)q-p+x$	$(u-p)q-x$	$vq-p+x$	$uq-p-x$	$(v+r)q-p+x$
$ac\ nb^+nb^-buy^0$	$-x$	$vq-p+x$	$-x$	$vq-p+x$	$-x$	$vq-p+x$	$-x$	$vq-p+x$
$ac\ nb^+buy^-nb^0$	$-x$	$vq-p+x$	$pq-p-x$	$(v+r)q-p+x$	$(u-p)q-x$	$vq-p+x$	$uq-p-x$	$(v+r)q-p+x$
$ac\ nb^+nb^-nb^0$	$-x$	$vq-p+x$	$-x$	$vq-p+x$	$-x$	$vq-p+x$	$-x$	$vq-p+x$
$ref\ buy^+buy^-buy^0$	$uq-p$	$vq-p$	$uq-p$	$vq-p$	$uq-p$	$vq-p$	$uq-p$	$vq-p$
$ref\ buy^+nb^-buy^0$	$uq-p$	$vq-p$	$uq-p$	$vq-p$	$uq-p$	$vq-p$	$uq-p$	$vq-p$
$ref\ buy^+buy^-nb^0$	0	$vq-p$	0	$vq-p$	0	$vq-p$	0	$vq-p$
$ref\ buy^+nb^-nb^0$	0	$vq-p$	0	$vq-p$	0	$vq-p$	0	$vq-p$
$ref\ nb^+buy^-buy^0$	$uq-p$	$vq-p$	$uq-p$	$vq-p$	$uq-p$	$vq-p$	$uq-p$	$vq-p$
$ref\ nb^+nb^-buy^0$	$uq-p$	$vq-p$	$uq-p$	$vq-p$	$uq-p$	$vq-p$	$uq-p$	$vq-p$
$ref\ nb^+buy^-nb^0$	0	$vq-p$	0	$vq-p$	0	$vq-p$	0	$vq-p$
$ref\ nb^+nb^-nb^0$	0	$vq-p$	0	$vq-p$	0	$vq-p$	0	$vq-p$

Table 2: The Normal-Form Representation of Model 2 in which the Players' best Responses are marked.

	Expert (Player 1)							
Buyer (Player 2)	reg^+reg^-		reg^+dis^-		dis^+reg^-		dis^+dis^-	
$ac\ buy^+buy^-buy^0$	$uq-p-x$	$(v+r)q-p+x$	$uq-p-x$	$(v-p+\underline{p})q-\underline{p}+x+r$	$uq-p-x$	$(v+p-\underline{p})q-p+x$	$uq-p-x$	$(v-r)q-\underline{p}+x+r$
$ac\ buy^+nb^-buy^0$	$uq-p-x$	$(v+r)q-p+x$	$(u-p)q-x$	$(v-p+\underline{p}+r)q-\underline{p}+x$	$pq-p-x$	$(v+p-\underline{p})q-p+x$	$-x$	$vq-\underline{p}+x$
$ac\ buy^+buy^-nb^0$	$uq-p-x$	$(v+r)q-p+x$	$uq-p-x$	$(v-p+\underline{p})q-\underline{p}+x+r$	$uq-p-x$	$(v+p-\underline{p})q-p+x$	$uq-p-x$	$(v-r)q-\underline{p}+x+r$
$ac\ buy^+nb^-nb^0$	$uq-p-x$	$(v+r)q-p+x$	$(u-p)q-x$	$(v-p+\underline{p}+r)q-\underline{p}+x$	$pq-p-x$	$(v+p-\underline{p})q-p+x$	$-x$	$vq-\underline{p}+x$
$ac\ nb^+buy^-buy^0$	$-x$	$vq-p+x$	$pq-p-x$	$(v-p+\underline{p}-r)q-\underline{p}+x+r$	$(u-p)q-x$	$(v+p-\underline{p})q-p+x$	$uq-p-x$	$(v-r)q-\underline{p}+x+r$
$ac\ nb^+nb^-buy^0$	$-x$	$vq-p+x$	$-x$	$(v-p+\underline{p})q-\underline{p}+x$	$-x$	$(v+p-\underline{p})q-p+x$	$-x$	$vq-\underline{p}+x$
$ac\ nb^+buy^-nb^0$	$-x$	$vq-p+x$	$pq-p-x$	$(v-p+\underline{p}-r)q-\underline{p}+x+r$	$(u-p)q-x$	$(v+p-\underline{p})q-p+x$	$uq-p-x$	$(v-r)q-\underline{p}+x+r$
$ac\ nb^+nb^-nb^0$	$-x$	$vq-p+x$	$-x$	$(v-p+\underline{p})q-\underline{p}+x$	$-x$	$(v+p-\underline{p})q-p+x$	$-x$	$vq-\underline{p}+x$
$ref\ buy^+buy^-buy^0$	$uq-p$	$vq-p$	$uq-p$	$q(v-p+\underline{p})-\underline{p}$	$uq-p$	$q(v+p-\underline{p})-p$	$uq-p$	$vq-p$
$ref\ buy^+nb^-buy^0$	$uq-p$	$vq-p$	$uq-p$	$q(v-p+\underline{p})-\underline{p}$	$uq-p$	$q(v+p-\underline{p})-p$	$uq-p$	$vq-p$
$ref\ buy^+buy^-nb^0$	0	$vq-p$	0	$q(v-p+\underline{p})-\underline{p}$	0	$q(v+p-\underline{p})-p$	0	$vq-p$
$ref\ buy^+nb^-nb^0$	0	$vq-p$	0	$q(v-p+\underline{p})-\underline{p}$	0	$q(v+p-\underline{p})-p$	0	$vq-p$
$ref\ nb^+buy^-buy^0$	$uq-p$	$vq-p$	$uq-p$	$q(v-p+\underline{p})-\underline{p}$	$uq-p$	$q(v+p-\underline{p})-p$	$uq-p$	$vq-p$
$ref\ nb^+nb^-buy^0$	$uq-p$	$vq-p$	$uq-p$	$q(v-p+\underline{p})-\underline{p}$	$uq-p$	$q(v+p-\underline{p})-p$	$uq-p$	$vq-p$
$ref\ nb^+buy^-nb^0$	0	$vq-p$	0	$q(v-p+\underline{p})-\underline{p}$	0	$q(v+p-\underline{p})-p$	0	$vq-p$
$ref\ nb^+nb^-nb^0$	0	$vq-p$	0	$q(v-p+\underline{p})-\underline{p}$	0	$q(v+p-\underline{p})-p$	0	$vq-p$

Table A.4: Sequential Equilibria in Model 1 under A1-A2

NE in Model 1 under $A1$-$A2$			
	Player 1	Player 2	Seq. Equilibrium
I	H^+L^-	$ac\ buy^+nb^-buy^0$	✓
II	H^+L^-	$ac\ buy^+nb^-nb^0$	×
III	L^+L^-	$ref\ buy^+buy^-buy^0$	✓
IV	L^+L^-	$ref\ nb^+buy^-buy^0$	✓
V	L^+L^-	$ref\ nb^+nb^-buy^0$	×
VI	L^+L^-	$ref\ buy^+nb^-buy^0$	×
VII	H^+H^-	$ref\ buy^+buy^-buy^0$	✓
VIII	H^+H^-	$ref\ nb^+nb^-buy^0$	×
IX	H^+H^-	$ref\ buy^+nb^-buy^0$	✓
X	H^+H^-	$ref\ nb^+buy^-buy^0$	×

- **Equilibrium V and VI:** For any completely mixed strategies b^m with $s_m = b_1^m(H^+) \to 0, t_m = b_1^m(H^-) \to 0$, consider the corresponding Bayesian consistent belief at the third information set as in (A.3): $\beta^{m3} \longrightarrow (q, 1-q)$. By sequential rationality, Player 2 plays buy^- at his third information set as $\mathbb{E}_2[\text{buy}^-] = (u-p-x)q + (-p-x)(1-q) = uq - p - x > -x = \mathbb{E}_2[\text{nb}^-]$.
- **Equilibrium VIII and X:** For any completely mixed strategies b^m with $s_m = b_1^m(H^+) \to 1, t_m = b_1^m(H^-) \to 1$, consider the corresponding Bayesian consistent belief at the second information set as in (A.2): $\beta^{m2} \longrightarrow (q, 1-q)$. By sequential rationality, Player 2 plays buy^+ at his second information set as $\mathbb{E}_2[\text{buy}^+] = (u-p-x)q + (-p-x)(1-q) = uq - p - x > -x = \mathbb{E}_2[\text{nb}^+]$.

Sequential equilibria in the game of Model 2

Consider again a completely mixed behavioral strategy (bi. b2) and the Bayesian consistent belief system g as described above. In Tables C.13 and A.7 we see that 3 out of 6 Nash equilibria are sequential and the corresponding belief systems. We remark that Equilibrium I shows the desired behavioral strategy and that the set of sequential equilibria in Model 2 is included in the set of those in Model 1.

Table A.5: Belief Systems for Equilibria in Model 1 under AI-A2: For the Sequence of Assessments, the Corresponding Bayesian Consistent Beliefs are Calculated as in (A.1)-(A.4)

Equilibrium	Belief System	Assessment Sequence ($m \geq 2$)
I	$\beta^1 = (q, 0, 0, 1-q)$ $\beta^2 = (1, 0)$ $\beta^3 = (0, 1)$ $\beta^4 = (q, 0, 0, 1-q)$	$b_1^m(H^+) = 1 - 1/m, b_1^m(H^-) = 1/m$ $b_2^m(ac) = 1 - 1/m, b_2^m(buy^-) = 1/m$ $b_2^m(buy^+) = b_2^m(buy^0) = 1 - 1/m$
III	$\beta^1 = (0, q, 0, 1-q)$ $\beta^2 = (q, 1-q)$ $\beta^3 = (q, 1-q)$ $\beta^4 = (0, q, 0, 1-q)$	$b_1^m(H^+) = b_1^m(H^-) = 1/m$ $b_2^m(ac) = 1/m, b_2^m(buy^+) = 1 - 1/m$ $b_2^m(buy^-) = b_2^m(buy^0) = 1 - 1/m$
IV	$\beta^1 = (0, q, 0, 1-q)$ $\beta^2 = (0, 1)$ $\beta^3 = (q, 1-q)$ $\beta^4 = (0, q, 0, 1-q)$	$b_1^m(H^+) = 1/m^2, b_1^m(H^-) = 1/m$ $b_2^m(ac) = b_2^m(buy^+) = 1/m$ $b_2^m(buy^-) = b_2^m(buy^0) = 1 - 1/m$
VII	$\beta^1 = (q, 0, 1-q, 0)$ $\beta^2 = (q, 1-q)$ $\beta^3 = (q, 1-q)$ $\beta^4 = (q, 0, 1-q, 0)$	$b_1^m(H^+) = b_1^m(H^-) = 1 - 1/m$ $b_2^m(ac) = 1/m, b_2^m(buy^+) = 1 - 1/m$ $b_2^m(buy^-) = b_2^m(buy^0) = 1 - 1/m$
IX	$\beta^1 = (q, 0, 1-q, 0)$ $\beta^2 = (q, 1-q)$ $\beta^3 = (0, 1)$ $\beta^4 = (q, 0, 1-q, 0)$	$b_1^m(H^+) = 1 - 1/m^2, b_1^m(H^-) = 1 - 1/m$ $b_2^m(ac) = 1/m, b_2^m(buy^-) = 1/m$ $b_2^m(buy^+) = b_2^m(buy^0) = 1 - 1/m$

The reasons behind the failure of the other equilibria are as follows:

- **Equilibrium II:** For any $b_1^m(reg^+), b_1^m(reg^-) \in (0,1)$, $\mathbb{E}_2[\text{buy}^0] > \mathbb{E}_2[\text{nb}^0]$ as $\mathbb{E}_2[\text{buy}^0] = (u-p)\beta_1^4 + (u-p)\beta_2^4 + (-p)\beta_3^4 + (-p)\beta_4^4 = (u-p)q - p(1-q) = uq - p > 0 = \mathbb{E}_2[\text{nb}^0]$. By sequential rationality, this equilibrium cannot be a sequential equilibrium.

- **Equilibrium V and VI:** For any completely mixed strategies b^m with $s_m = b_1^m(reg^+) \to 0, t_m = b_1^m(reg^-) \to 0$, consider the corresponding Bayesian consistent belief at the third information set as in (A.3): $\beta^{m3} \longrightarrow (q, 1-q)$. By sequential rationality, Player 2 plays buy^- at his third information set as $\mathbb{E}_2[\text{buy}^-] = (u-p-x)q + (-p-x)(1-q) = uq - p - x > -x = \mathbb{E}_2[\text{nb}^-]$.

Appendix B: Determination of Nash and Sequential Equilibria under A1', A2', and A3

We proceed as in the previous section and give the distinction between Nash and sequential equilibria in Model 1 (Model 2) in Table B.8 (Table B.10) as well as the corresponding belief systems in Tables B.9 and B.11 followed by the contradictions that the remaining Nash equilibria are not sequential.

Table A.6: Sequential Equilibria in Model 2 under AI-A3

NE in Model 2 under $A1$-$A3$			
	Player 1	Player 2	SE
I	$reg^{+}dis^{-}$	$ac\ buy^{+}nb^{-}buy^{0}$	✓
II	$reg^{+}dis^{-}$	$ac\ buy^{+}nb^{-}nb^{0}$	×
III	$dis^{+}dis^{-}$	$ref\ buy^{+}buy^{-}buy^{0}$	✓
IV	$dis^{+}dis^{-}$	$ref\ nb^{+}buy^{-}buy^{0}$	✓
V	$dis^{+}dis^{-}$	$ref\ nb^{+}nb^{-}buy^{0}$	×
VI	$dis^{+}dis^{-}$	$ref\ buy^{+}nb^{-}buy^{0}$	×

Table A.7: Belief Systems for Equilibria in Model 2 under AI-A3: For the Sequence of Assessments, the Corresponding Bayesian Consistent Beliefs are Calculated as in (A.1)-(A.4)

Equilibrium	Belief System	Assessment Sequence ($m \geq 2$)
I	$\beta^{1} = (q,0,0,1-q)$ $\beta^{2} = (1,0)$ $\beta^{3} = (0,1)$ $\beta^{4} = (q,0,0,1-q)$	$b_1^m(reg^+) = 1 - 1/m, b_1^m(reg^-) = 1/m$ $b_2^m(ac) = 1 - 1/m, b_2^m(buy^-) = 1/m$ $b_2^m(buy^+) = b_2^m(buy^0) = 1 - 1/m$
III	$\beta^{1} = (0,q,0,1-q)$ $\beta^{2} = (q,1-q)$ $\beta^{3} = (q,1-q)$ $\beta^{4} = (0,q,0,1-q)$	$b_1^m(reg^+) = b_1^m(reg^-) = 1/m$ $b_2^m(ac) = 1/m, b_2^m(buy^+) = 1 - 1/m$ $b_2^m(buy^-) = b_2^m(buy^0) = 1 - 1/m$
IV	$\beta^{1} = (0,q,0,1-q)$ $\beta^{2} = (0,1)$ $\beta^{3} = (q,1-q)$ $\beta^{4} = (0,q,0,1-q)$	$b_1^m(reg^+) = 1/m^2, b_1^m(reg^-) = 1/m$ $b_2^m(ac) = b_2^m(buy^+) = 1/m$ $b_2^m(buy^-) = b_2^m(buy^0) = 1 - 1/m$

Again, the set of equilibria shrinks when moving from Model 1 to Model 2. Under the as- sumptions the desired strategy here requires the buyer not to buy the product when uninformed. It is part of the sequential equilibrium II and prevails in both models.

Reasoning for the non-sequential equilibria in Model 1:

- **Equilibrium I** For any $b_1^m(H^+), b_1^m(H^-) \in (0,1)$, $\mathbb{E}_2[\text{buy}^0] < \mathbb{E}_2[\text{nb}^0]$ as $\mathbb{E}_2[\text{buy}^0] = (u - p)\beta_1^4 + (u-p)\beta_2^4 + (-p)\beta_3^4 + (-p)\beta_4^4 = (u-p)q - p(1-q) = uq - p < 0 = \mathbb{E}_2[\text{nb}^0]$. By sequential rationality, this equilibrium cannot be a sequential equilibrium.

- **Equilibrium III and IV** For any completely mixed strategies b^m with $s_m = b_1^m(H^+) \to 0, t_m = b_1^m(H^-) \to 0$, consider the corresponding Bayesian consistent belief at the third information set as in (A.3): $\beta^{m3} \longrightarrow (q, 1-q)$. By sequential rationality, Player 2 plays nb^- at his third information set as $\mathbb{E}_2[\text{buy}^-] = (u-p-x)q + (-p-x)(1-q) = uq - p - x < -x = \mathbb{E}_2[\text{nb}^-]$.

- **Equilibrium VII and IX** For any completely mixed strategies b^m with $s_m = b_1^m(H^+) \to 1, t_m = b_1^m(H^-) \to 1$, consider the corresponding Bayesian consistent belief at the second information set as in (A.2): $\beta^{m2} \longrightarrow (q, 1-q)$. By sequential rationality, Player 2 plays nb^+ at his second information set as $\mathbb{E}_2[\text{buy}^+] = (u-p-x)q + (-p-x)(1-q) = uq - p - x < -x = \mathbb{E}_2[\text{nb}^+]$.

Table B.8: Sequential Equilibria in Model 1 under the Assumptions A1', and A2': from Table A.2, it is easy to see that there are 10 Nash Equlibria in Pure Strategies under the Assumptions

NE in Model 1 under $A1'$, and $A2'$			
	Player 1	Player 2	SE
I	H^+L^-	$ac\ buy^+nb^-buy^0$	×
II	H^+L^-	$ac\ buy^+nb^-nb^0$	✓
III	L^+L^-	$ref\ buy^+buy^-nb^0$	×
IV	L^+L^-	$ref\ nb^+buy^-nb^0$	×
V	L^+L^-	$ref\ nb^+nb^-nb^0$	✓
VI	L^+L^-	$ref\ buy^+nb^-nb^0$	✓
VII	H^+H^-	$ref\ buy^+buy^-nb^0$	×
VIII	H^+H^-	$ref\ nb^+nb^-nb^0$	✓
IX	H^+H^-	$ref\ buy^+nb^-nb^0$	×
X	H^+H^-	$ref\ nb^+buy^-nb^0$	✓

Table B.9: Belief Systems for Equlibria in Model 1 under A1', and A2': for the Sequence of Assessments, the Corresponding Bayesian Beliefs are Calculated as in (A.1)-(A.4)

Equilibrium	Belief System	Assessment Sequence ($m \geq 2$)
II	$\beta^1 = (q, 0, 0, 1-q)$ $\beta^2 = (1, 0)$ $\beta^3 = (0, 1)$ $\beta^4 = (q, 0, 0, 1-q)$	$b_1^m(H^+) = 1 - 1/m, b_1^m(H^-) = 1/m$ $b_2^m(ac) = b_2^m(buy^+) = 1 - 1/m$ $b_2^m(buy^-) = b_2^m(buy^0) = 1/m$
V	$\beta^1 = (0, q, 0, 1-q)$ $\beta^2 = (q, 1-q)$ $\beta^3 = (q, 1-q)$ $\beta^4 = (0, q, 0, 1-q)$	$b_1^m(H^+) = b_1^m(H^-) = 1/m$ $b_2^m(ac) = b_2^m(buy^+) = 1/m$ $b_2^m(buy^-) = b_2^m(buy^0) = 1/m$
VI	$\beta^1 = (0, q, 0, 1-q)$ $\beta^2 = (1, 0)$ $\beta^3 = (q, 1-q)$ $\beta^4 = (0, q, 0, 1-q)$	$b_1^m(H^+) = 1/m, b_1^m(H^-) = 1/m^2$ $b_2^m(ac) = 1/m, b_2^m(buy^+) = 1 - 1/m$ $b_2^m(buy^-) = b_2^m(buy^0) = 1/m$
VIII	$\beta^1 = (q, 0, 1-q, 0)$ $\beta^2 = (q, 1-q)$ $\beta^3 = (q, 1-q)$ $\beta^4 = (q, 0, 1-q, 0)$	$b_1^m(H^+) = b_1^m(H^-) = 1 - 1/m$ $b_2^m(ac) = b_2^m(buy^+) = 1/m$ $b_2^m(buy^-) = b_2^m(buy^0) = 1/m$
X	$\beta^1 = (q, 0, 1-q, 0)$ $\beta^2 = (q, 1-q)$ $\beta^3 = (1, 0)$ $\beta^4 = (q, 0, 1-q, 0)$	$b_1^m(H^+) = 1 - 1/m, b_1^m(H^-) = 1 - 1/m^2$ $b_2^m(ac) = 1/m, b_2^m(buy^-) = 1 - 1/m$ $b_2^m(buy^+) = b_2^m(buy^0) = 1/m$

Nonsequential equilibria in Model 2:

- **Equilibrium I:** For any $b_1^m(reg^+), b_1^m(reg^-) \in (0,1)$, $\mathbb{E}_2[\text{buy}^0] < \mathbb{E}_2[\text{nb}^0]$ as $\mathbb{E}_2[\text{buy}^0] = (u-p)\beta_1^4 + (u-p)\beta_2^4 + (-p)\beta_3^4 + (-p)\beta_4^4 = (u-p)q - p(1-q) = uq - p < 0 = \mathbb{E}_2[\text{nb}^0]$. By sequential rationality, this equilibrium cannot be a sequential equilibrium.

- **Equilibrium III and IV:** For any completely mixed strategies b^m with $s_m = b_1^m(reg^+) \to 0, t_m = b_1^m(reg^-) \to 0$, consider the corresponding Bayesian consistent belief at the third information set as in (A.3): $\beta^{m3} \longrightarrow (q, 1-q)$. By sequential rationality, Player 2 plays nb^- at his third information set as $\mathbb{E}_2[\text{buy}^-] = (u-p-x)q + (-p-x)(1-q) = uq - p - x < -x = \mathbb{E}_2[\text{nb}^-]$.

Appendix C: Determination of sequential equilibria when uq — p = 0

Under the assumption uq — p = 0, i.e., the uninformed buyer is indifferent between buying and not buying, Model 1 has 18 pure strategy Nash equilibria that can be found via the normal- form representation of that simultaneous move game in Table 37. Similarly, there are 10 pure strategy Nash equilibria of Model 2 via Table 38. What is different to the previous sections is that all Nash equilibria are also sequential equilibria. Moreover, the set of sequential equilibria in either model is the union of the sets of sequential equilibria given in Appendix A and Appendix B.

We present for each model separately the sets of equilibria and demonstrate that they are sequential.

Table B.10: Sequential Equilibria in Model 2 under A1', A2' and A3'

NE in Model 2 under $A1'$, $A2'$, and $A3$			
	Player 1	Player 2	SE
I	$reg^+ dis^-$	$ac\ buy^+ nb^- buy^0$	×
II	$reg^+ dis^-$	$ac\ buy^+ nb^- nb^0$	✓
III	$dis^+ dis^-$	$ref\ buy^+ buy^- nb^0$	×
IV	$dis^+ dis^-$	$ref\ nb^+ buy^- nb^0$	×
V	$dis^+ dis^-$	$ref\ nb^+ nb^- nb^0$	✓
VI	$dis^+ dis^-$	$ref\ buy^+ nb^- nb^0$	✓

Table B.11: Belief Systems for Equilibria in Model 2 under Al', A2', and A3: For the Sequence of Assessments, the Corresponding Bayesian Consistent Beliefs are Calculated as in (A.1)-(A.4)

Equilibrium	Belief System	Assessment Sequence ($m \geq 2$)
II	$\beta^1 = (q,0,0,1-q)$ $\beta^2 = (1,0)$ $\beta^3 = (0,1)$ $\beta^4 = (q,0,0,1-q)$	$b_1^m(reg^+) = 1 - 1/m, b_1^m(reg^-) = 1/m$ $b_2^m(ac) = b_2^m(buy^+) = 1 - 1/m$ $b_2^m(buy^-) = b_2^m(buy^0) = 1/m$
V	$\beta^1 = (0,q,0,1-q)$ $\beta^2 = (1,0)$ $\beta^3 = (q,1-q)$ $\beta^4 = (0,q,0,1-q)$	$b_1^m(reg^+) = 1/m, b_1^m(reg^-) = 1/m^2$ $b_2^m(ac) = b_2^m(buy^+) = 1/m$ $b_2^m(buy^-) = b_2^m(buy^0) = 1/m$
VI	$\beta^1 = (0,q,0,1-q)$ $\beta^2 = (1,0)$ $\beta^3 = (q,1-q)$ $\beta^4 = (0,q,0,1-q)$	$b_1^m(reg^+) = 1/m, b_1^m(reg^-) = 1/m^2$ $b_2^m(ac) = b_2^m(buy^-) = 1/m$ $b_2^m(buy^+) = 1 - 1/m, b_2^m(buy^0) = 1/m$

Before going into the details of why all equilibria are sequential, an observation regarding to the equilibrium behavior of Player 2 is worth noting: Unlike Appendix A and Appendix B, Player 2 is indifferent between the alternatives at the fourth information set, i.e., $\mathbb{E}_2[\text{buy}^0] = \mathbb{E}_2[\text{nb}^0]$ for any b, β as $\mathbb{E}_2[\text{buy}^0] = (u-p)\beta_1^4 + (u-p)\beta_2^4 + (-p)\beta_3^4 + (-p)\beta_4^4 = (u-p)q - p(1-q) = uq - p = 0 = \mathbb{E}_2[\text{nb}^0]$.

- **Equilibrium I:** Consider the following completely mixed behavioral strategies: $b_1^m(H^+) = 1 - 1/m \to 1, b_1^m(H^-) = 1/m \to 0$, and $b_2^m(ac) = 1 - 1/m \to 1$, $b_2^m(buy^+) = 1 - 1/m \to 1, b_2^m(buy^-) = \frac{1}{m} \to 0, b_2^m(buy^0) \in (0,1)$. The corresponding Bayesian consistent belief system is constructed as in Appendix A as follows: $\beta^{m1} \to (q,0,0,1-q) := \beta^1, \beta^{m2} \to (1,0) := \beta^2, \beta^{m3} \to (0,1) := \beta^3, \beta^{m4} \to (q,0,0,1-q) := \beta^4$.

Table C.13: The Sequential Equilibria of Model 1 when uq = p

NE in Model 1 when $uq = p$			
	Player 1	Player 2	SE
I	H^+L^-	$ac\ buy^+nb^-buy^0$	✓
		$ac\ buy^+nb^-nb^0$	✓
II	L^+L^-	$ref\ buy^+buy^-buy^0$	✓
		$ref\ nb^+buy^-buy^0$	✓
		$ref\ nb^+nb^-buy^0$	✓
		$ref\ buy^+nb^-buy^0$	✓
		$ref\ buy^+buy^-nb^0$	✓
		$ref\ nb^+buy^-nb^0$	✓
		$ref\ nb^+nb^-nb^0$	✓
		$ref\ buy^+nb^-nb^0$	✓
III	H^+H^-	$ref\ buy^+buy^-buy^0$	✓
		$ref\ nb^+nb^-buy^0$	✓
		$ref\ buy^+nb^-buy^0$	✓
		$ref\ nb^+buy^-buy^0$	✓
		$ref\ buy^+buy^-nb^0$	✓
		$ref\ nb^+nb^-nb^0$	✓
		$ref\ buy^+nb^-nb^0$	✓
		$ref\ nb^+buy^-nb^0$	✓

- **Equilibrium II:** Consider the following completely mixed behavioral strategies: $b_1^m(H^+) = b_1^m(H^-) = \frac{1}{m} \to 0$, and $b_2^m(ac) = \frac{1}{m} \to 0$, $b_2^m(buy^+), b_2^m(buy^-), b_2^m(buy^0) \in (0,1)$ for any $m \geq 2$. The associated beliefs with b^m satisfying Bayesian consistency are $\beta^{m1} \to (0,q,0,1-q) := \beta^1, \beta^{m2} \to (q,1-q) := \beta^2, \beta^{m3} \to (q,1-q) := \beta^3 \text{and} \beta^{m4} \to (0,q,0,1-q) := \beta^4$. Then, Player 2 is indifferent at all information sets except the first one.

- **Equilibrium III:** Consider the following completely mixed behavioral strategies: $b_1^m(H^+) = b_1^m(H^-) = 1 - \frac{1}{m} \to 1$, and $b_2^m(ac) = \frac{1}{m} \to 0$, $b_2^m(buy^+), b_2^m(buy^-), b_2^m(buy^0) \in (0,1)$ for all $m \geq 2$. The associated beliefs with b^m satisfying Bayesian consistency are $\beta^{m1} \to (q,0,1-q,0) := \beta^1, \beta^{m2} \to (q,1-q) := \beta^2, \beta^{m3} \to (q,1-q) := \beta^3 \text{and} \beta^{m4} \to (q,0,1-q,0) := \beta^4$. Again, Player 2 is indifferent at all information sets except the first one.

The observation which was done above for Model 1 remains valid for Model 2, i.e., Player 2 is indifferent between the alternatives at the fourth information set.

- **Equilibrium I:** Consider $b_1^m(reg^+) = 1 - \frac{1}{m} \to 1$, $b_1^m(reg^-) = \frac{1}{m} \to 0$, $b_2^m(ac) = 1 - \frac{1}{m} \to 1$, $b_2^m(buy^+) = 1 - \frac{1}{m} \to 1$, $b_2^m(buy^-) = \frac{1}{m} \to 0$ and $b_2^m(buy^0) \in (0,1)$. Based on this behavioral strategies, Bayesian consistency implies β^m, the computed beliefs above: $\beta^{m1} \to (q,0,0,1-q) := \beta^1, \beta^{m2} \to (1,0) := \beta^2, \beta^{m3} \to (0,1) := \beta^3, \beta^{m4} \to (q,0,0,1-q) := \beta^4$.

Table 3: The Sequential Equilibria of Model 2 when uq = p

NE in Model 2 when $uq = p$			
	Player 1	Player 2	SE
I	reg^+dis^-	$ac\ buy^+nb^-buy^0$	✓
	reg^+dis^-	$ac\ buy^+nb^-nb^0$	✓
II	dis^+dis^-	$ref\ buy^+buy^-buy^0$	✓
	dis^+dis^-	$ref\ nb^+buy^-buy^0$	✓
	dis^+dis^-	$ref\ nb^+nb^-buy^0$	✓
	dis^+dis^-	$ref\ buy^+nb^-buy^0$	✓
	dis^+dis^-	$ref\ buy^+buy^-nb^0$	✓
	dis^+dis^-	$ref\ nb^+buy^-nb^0$	✓
	dis^+dis^-	$ref\ nb^+nb^-nb^0$	✓
	dis^+dis^-	$ref\ buy^+nb^-nb^0$	✓

- **Equilibrium II:** Consider $b_1^m(reg^+) = b_1^m(reg^-) = \frac{1}{m} \to 1, b_2^m(ac) = \frac{1}{m} \to 0, b_2^m(buy^+)$, $b_2^m(buy^-), b_2^m(buy^0) \in (0,1)$. These strategies lead to the Bayesian consistent beliefs in the way described above, so $\beta^{m1} \to (0,q,0,1-q) := \beta^1, \beta^{m2} \to (q,1-q) := \beta^2, \beta^{m3} \to (q,1-q) := \beta^3, \beta^{m4} \to (0,q,0,1-q) := \beta^4$.