SONDERFORSCHUNGSBEREICH 504

Rationalitätskonzepte,
Entscheidungsverhalten und
ökonomische Modellierung

No. 05-39

Alternating Offer Bargaining with Endogenous Information: Timing and Surplus Division

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March 2005

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This Draft: November 2005

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Abstract

Two ex ante identically informed agents play a two-period alternating offer bargaining game over the division of a trading surplus with endogenous information acquisition and common values. Because of endogenous lemons problems and endogenous outside options perfect equilibria may have the following properties. (1) In the one period case the agent responding to a take-it-or-leave-it offer captures the full trading surplus. (2) If the discounting of the trading surplus is lower than the discounting of the information cost, delay of agreement arises although the agents maintain symmetric information in the period of disagreement. (3) The equilibrium payoffs of the agents are non-monotonic in the discount factor of the trading surplus.

Key words: bargaining, delay, endogenous lemons problem, endogenous outside option, information acquisition

JEL Classification Numbers: C78, D82, D83

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* I am indebted to Martin Hellwig for critical discussions and ongoing suggestions. I thank Ernst Ludwig von Thadden for comments. Financial support from the Deutsche Forschungsgemeinschaft (DFG) through the Graduiertenkolleg at the University of Mannheim is gratefully acknowledged. Postal Address: L7, 3-5; 68131 Mannheim, Germany. Email: dang@pool.uni-mannheim.de

1. Introduction

This paper analyses information acquisition in alternating offer bargaining. A risk neutral buyer and a risk neutral seller seek to agree on a price at which to trade an asset with a significant common value (quality) component. Ex ante both agents are identically informed about all relevant aspects of trade. In particular, it is common knowledge that a trading surplus exists and both agents have symmetric information about the uncertain quality of the asset. However, in each bargaining round prior to making an offer or a response an agent can acquire information about the true quality.[1]

This paper focuses on two-period alternating-offer bargaining in such an environment and shows that perfect equilibria may have the following properties. (1) In the one period game the agent responding to a take-it-or-leave-it-offer captures the trading full surplus. Whether there is a first mover or second mover advantage in ultimatum bargaining depends on the information cost. (2) If the discounting of the trading surplus is lower than the discounting of the information cost an endogenous lemons problem causes delay of agreement although in the period of disagreement the agents may maintain symmetric information. (3) Because of endogenous outside options the equilibrium payoffs of the agents are non-monotonic in the discount factor δ of the trading surplus. In particular, the equilibrium payoff of the first period proposer can increase in δ.

The driving force for these results is that endogenous information acquisition in a common values environment exerts two effects. It can cause an endogenous lemons problem and it implies that the outside options of the agents are endogenous. These two consequences give rise to a rich set of strategic considerations. It is common knowledge that the asset is worth $v+\Delta$ to the buyer and $v-\Delta$ to the seller where v is the uncertain common value component (quality) of the asset. For any quality level v, the buyer's valuation exceeds the seller's valuation by the amount 2Δ which represents the trading surplus. Ex ante both agents have identical information about quality, but prior to making an offer and a response they can acquire information about the true quality. Suppose that the buyer makes an offer in the first period. If the seller rejects the offer the seller makes an offer in the second period.

[1] For example, agents trading financial assets might face common values uncertainty because of the underlying risky cash flow stream. In particular, in secondary markets the seller of a financial asset does not necessarily possess better information about the value of the asset than a potential buyer. Irrespective of asset ownership, any agent can spent resources to obtain information about the asset.

The intuition why in the one period game, perfect equilbria exist in which the agent responding to a take-it-or-leave-it-offer captures some or even the full trading surplus is the following. Suppose that the information cost c is larger than the total surplus (i.e. $c>2\Delta$) so that the buyer does not acquire information in equilibrium. Suppose the uninformed buyer is willing to give the full surplus 2Δ to the seller and proposes $E[v]+\Delta$. If the seller accepts the offer he gets the expected payoff 2Δ. Alternatively, the seller acquires information and tries to exploit the buyer. If he sees that the quality of the asset is high, he rejects the offer. If he sees that the quality is low, he accepts the offer. In this case the uninformed buyer suffers an endogenous lemons problem while the informed seller realizes the trading surplus as well as makes some speculative profits. However, ex ante speculation causes an opportunity cost in the sense that the seller forgoes some surplus because there is no trade in the high state.

So if an uninformed buyer offers the seller the full trading surplus and if the information cost c is larger than the expected speculative profit π net the expected opportunity cost of speculation c^{Spec} then the seller accepts the offer without information acquisition and gets 2Δ. On the other hand if the buyer wants to capture the full trading surplus then the seller faces no opportunity cost of speculation. If $c<\pi$ then the seller acquires information and speculates instead of just getting zero payoff. Therefore, if $\pi-c^{Spec}<c<\pi$ there exists a critical offer which the seller accepts without information acquisition. This offer must give the seller some trading surplus.

The possibility to acquire information endows the responder with a credible threat in the sense of saying, that if he does no get enough trading surplus he acquires information and exploits the uninformed proposer. In particular, for $2\Delta\leq c=\pi-c^{Spec}$, in any perfect equilibrium the buyer as the proposer gets zero payoff and a perfect equilibrium exists in which the seller as the responder to a take-it-or-leave-it-offer captures the full trading surplus. Whether there is a first-mover or second-mover advantage in ultimatum bargaining depends on the information cost.

The argument above also shows that if the information cost is smaller than the speculative profit net the maximal opportunity cost of speculation, the buyer will not propose an offer which reflects the average quality of the asset. Because of the endogenous lemons problem an uninformed buyer proposes a more defensive offer which an uninformed seller does not accept. In such a case no trade occurs without information acquisition. So if $2\Delta<c<\pi-c^{Spec}$ then no equilibrium with agreement exists although the agents maintain symmetric information.[2] If $c<\min\{2\Delta, \pi-c^{Spec}\}$, then a least one agent acquires information in any trading equilibrium.

For the two period case, the intuition behind the waiting-to-agree result is as follows. Given the endogenous lemons concern, if the discounting of the trading surplus is lower than the discounting of the information cost then this can cause delay. Since the seller makes an offer in the final bargaining period he may capture the discounted trading surplus net the discounted information cost. Therefore, the seller rejects any offer which gives him less than what he can get as the proposer in the last period. Since the discounting of the trading surplus is low and the discounting of the information cost is high, the net surplus in the last period is relatively large. In order to induce trade in the first period the buyer has to make an attractive offer to the seller as well as to acquire information in order to avoid the endogenous lemons problem. However, if the remaining surplus the buyer can capture does not cover the information cost the buyer does not acquire information. The best responses of the agents in the first period are such that no agent acquires information, the buyer account for the endogenous lemons problem and submits a low offer which the uninformed seller does not accept.

Since the agents maintain symmetric information in the first period delay is not caused by signaling.[3] This observation is similar to Ingersoll and Ross (1992) who derive an optimal waiting time argument to invest under uncertainty without strategic interactions. This paper proposes a kind of waiting-to-agree-result or optimal timing argument to invest in information subject to an endogenous lemons constraint. If information is acquired in equilibrium then it is efficient to delay information acquisition and trade.

The third results states that the equilibrium payoffs of the agents are non-monotonic in the discount factor δ of the trading surplus. In particular, the equilibrium payoff of the

[2] This no efficient trade result is neither driven by asymmetric information about the common valuation as in Akerlof (1970), Samuelson (1984), or Gresik (1991) nor by asymmetric information about the private valuation as in Myerson and Satterthwhaite (1983) but by potential asymmetric information about the common valuation due to endogenous information acquisition.

[3] The bargaining literature provides as a dominant reason for delay a signaling or screening story due to (actual) asymmetric information. Admati and Perry (1987) and Cramton (1992) show that asymmetric information about the private valuation of the asset can cause delay. Evans (1989) and Vincent (1989) show that asymmetric information about the common valuation can lead to delay, too. See also Cho (1990), Watson (1998), Feinberg and Skrzypacz (2005), and the survey in Ausubel, et al. (2000). Fernandez and Glaser (1991) propose a delay story without asymmetric information. In their model a firm and an union bargain over a wage contract which holds for infinitely many periods (or transactions).

buyer (first period proposer) can increase in δ. The intuition is the following. There exist parameter constellations (i.e. $2\delta\Delta<c_1<\pi-c^{Spec}$) such that no trade occurs at all and the continuation payoff of the seller is zero if no agent acquires information in period 0. In period 0 the buyer faces a trade-off when comparing the following two alternatives.

(a) If the buyer acquires information the continuation payoff of the seller is positive. Since the buyer is informed trade occurs with positive probability in period 1 and the seller can capture some surplus in period 1. Information acquisition exerts a positive externality. (b) If the buyer does not acquire information but induces the seller to acquire information in period 0 by just compensating him for the information cost, the buyer can keep the continuation payoff of the seller at zero. The uninformed buyer accounts for the lemons problem. In the first period trade only occurs in the low state. If there is no trade then in the second period the seller is informed and the surplus $2\delta\Delta$ can be realized with positive probability. With an appropriate offer, the buyer can capture this additional surplus in the first period. The seller may accept the offer because his continuation payoff is anyway zero. There exist parameter constellations such that the buyer chooses this alternative so that his payoff increases in δ.

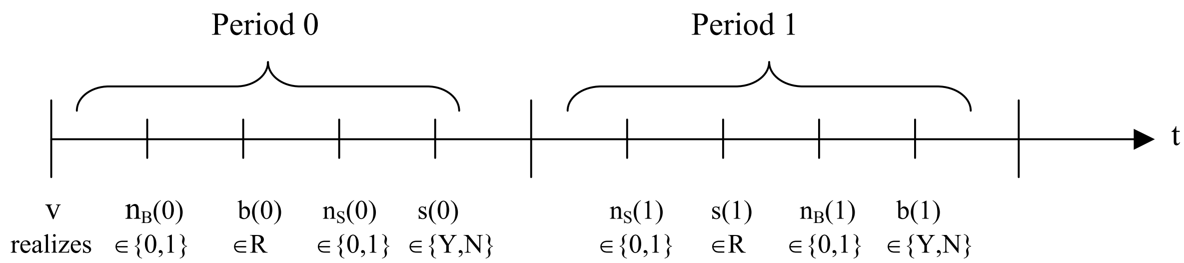
The remainder of the paper is organized as follows. The next section introduces the model. Section 3 analyzes take-it-or-leave-it offer bargaining and shows that the equilibrium payoffs of the agents are non-monotonic in the information cost. Section 4 analyzes two-period alternating offer bargaining and shows that the equilibrium payoffs of the agents are non-monotonic in the discounting of the trading surplus. Section 5 discusses the results as well as T-period alternating offer bargaining. Section 6 concludes. Appendix A and B contain the proofs of the Propositions.

2. The Model

Two risk neutral agents play a T period alternating offer bargaining game and seek to agree on a price p_t at which to trade an asset. It is common knowledge that the asset is worth $v+\Delta_t$ to the buyer and $v-\Delta_t$ to the seller in period t. $2\Delta_t$ captures the differences in valuation between the buyer and the seller where $\Delta_t=\delta^t\cdot\Delta$ with $\delta\in[0,1]$ and $\Delta>0$. v is the uncertain common value component (quality) which is either v_L or v_H with equal probability where $v_H>v_L>\Delta$. If trade occurs in period t, the surplus $2\Delta_t$ is realized and $U^B=(v+\Delta_t)-p_t$ and $U^S=p_t-(v-\Delta_t)$. If no agreement is reached until period T, the payoffs of the agents are normalized to zero.

In period t=0,2,4,.. the buyer's action is to acquire $n_B(t)\in\{0,1\}$ unit of information and then to choose an offer $b(t)\in R$. The seller's action is to acquire $n_S(t)\in\{0,1\}$ unit of information and to choose a response $s(t)\in\{Y,N\}$ to b(t). If s(t)=Y, trade occurs at the price b(t) and the game ends. Otherwise, the next bargaining period begins. In period t=1,3,... the seller chooses $n_S(t)\in\{0,1\}$ and $s(t)\in R$ and the buyer chooses $n_B(t)\in\{0,1\}$ and $b(t)\in\{Y,N\}$. If an agent acquires information he knows the true value v. Information acquisition is observable and the information cost is c_t where $c_t \geq c_{t+1}$. All actions of the agents are mutually observable. The solution concept is Perfect (Bayesian) Equilibrium (PE). The sequence of actions is depicted in Figure 1.

Figure 1



3. One-Period Bargaining

This section analyzes ultimatum bargaining where the buyer makes a take-it-or-leave-it offer which the seller either accepts or rejects. Then the game ends. The Pareto optimal outcome is trade without costly information acquisition irrespective of how the surplus is divided. This section shows that the set of perfect equilibria (PE) depends on the information cost and may have the following properties. (i) If the information cost c is low, the buyer acquires information and only he captures some surplus. If c is in an intermediate range then three cases can arise. (ii) No PE with trade exists. (iii) No agent acquires information and both agents capture some surplus. (iv) No agent acquires information and the seller captures the full surplus. (v) If c is high then no agent acquires information and the buyer captures the full surplus. Whether there is a first or second mover advantage in take-it-or-leave-it offer bargaining depends on the information cost. The time index is omitted in this section.

To get started, suppose that the information cost is high and the buyer does not acquire information and is willing to offer the seller the full surplus 2Δ by proposing the price $b=E[v]+\Delta$. The seller has two potential profitable responses. (i) The seller accepts this offer and chooses s=Y. He gets $EU^S=2\Delta$ and the buyer obtains $EU^B=0$. (ii) The seller acquires information and chooses s=Y if he sees that $v=v_L$; and s=N if he sees $v=v_H$. An agreement is only reached at $v=v_L$ and in this case trade is executed at the price $p=E[v]+\Delta=\frac{1}{2}(v_H+v_L)+\Delta$. The seller's payoff is $EU^S=\frac{1}{2}[p-(v_L-\Delta)]-c=\frac{1}{4}(v_H-v_L)+\Delta-c$.

The second strategy dominates the first one if $\frac{1}{4}(v_H-v_L)+\Delta-c>2\Delta$ which is the case for $c<\frac{1}{4}(v_H-v_L)-\Delta$. While $\frac{1}{4}(v_H-v_L)$ is the expected speculative profit an informed seller makes, Δ can be interpreted as the expected opportunity cost of speculation. If the seller speculates no trade occurs in the state v_H and ex ante he forgoes with probability 0.5 the surplus 2Δ. This argument shows that in such a case the seller wants to acquire information and exploit the uninformed buyer *although* he is offered the full surplus. Given response (ii), the payoff of the uninformed buyer is $EU^B=\frac{1}{2}[(v_L+\Delta)-p]=-\frac{1}{4}(v_H-v_L)$. So if $c<\frac{1}{4}(v_H-v_L)-\Delta$ the buyer does not propose an offer which reflects the average quality of the asset. He has to submit a defensive offer so as to account for the endogenous lemons problem.

Proposition 1 shows that if the information cost c is higher than the maximum surplus an *informed* buyer can capture (in any mixed strategy trading equilibrium) the buyer does not acquire information. Secondly, If c is also higher than the trading surplus an uninformed buyer can capture when providing the seller an incentive to acquire information by just compensating him for c, the buyer does not do this either. The maximum price an uninformed buyer is willing to propose is his expected valuation $E[v]+\Delta$. The minimum price an uninformed seller is willing to accept is his expected valuation $E[v]-\Delta$. However, since $c<\frac{1}{4}(v_H-v_L)-\Delta$ the buyer does not offer any price within this interval because of the endogenous lemons concern. He proposes a lower price which an uninformed seller does not accept. Therefore, no agreement arises although in the no trade equilibrium the buyer and seller maintain symmetric information.[4]

[4] This no efficient trade result is neither driven by asymmetric information about the common valuation as in Akerlof (1970), Samuelson (1984), or Gresik (1991) nor by asymmetric information about the private valuation as in Myerson and Satterthwhaite (1983) but by potential lemons problems due to endogenous information acquisition. It is not only actual asymmetric information but potential information asymmetry can already render efficient trade unattractive. Dang (2005) shows that a no-trade result also holds (i) in double-auction bargaining and (ii) for the case where the state space is a continuous random variable and the agents can acquire $n\in N$ units of information.

Proposition 1

If $2k\Delta<c<\frac{1}{4}(v_H-v_L)-\Delta$ the set of PE is given as follows. The buyer chooses n_B=0 and $b<v_L-\Delta+2c$ and the seller chooses n_S=0 and s=N. No PE with trade exists.

For a formal statement of k where $k\in(\frac{1}{2},1)$ see Step 3 in Appendix A. The argument above also shows that if the buyer offers E[v]+Δ and the information cost is larger than the expected speculative profit net the expected opportunity cost of speculation, i.e. $c\geq\frac{1}{4}(v_H-v_L)-\Delta$, then the seller accepts the offer without information acquisition and gets $EU^S=2\Delta$. On the other hand if the buyer offers E[v]−Δ and if $c<\frac{1}{4}(v_H-v_L)$, the seller acquires information and speculates instead of just getting $EU^S=0$. Therefore, if $\frac{1}{4}(v_H-v_L)-\Delta<c<\frac{1}{4}(v_H-v_L)$, there exists a critical offer which the seller accepts without information acquisition. This offer must give the seller some trading surplus.

Proposition 2

If $\max\{\frac{2}{3}\Delta(k-1)+\frac{1}{6}(v_H-v_L),\ \frac{1}{4}(v_H-v_L)-\Delta\}<c<\frac{1}{4}(v_H-v_L)$ then in the unique PE the buyer chooses n_B=0 and $b=v_H-\Delta-2c$ and the seller chooses n_S=0 and s=Y. Trade occurs with probability 1 and $EU^B=2\Delta+2c-\frac{1}{2}(v_H-v_L)$ and $EU^S=\frac{1}{2}(v_H-v_L)-2c$.

Proposition 2 shows that the agent responding to a take-it-or-leave-offer captures some trading surplus. The possibility to acquire information endows the responder with a credible speculative threat in the sense of saying, that if he does no get enough trading surplus he acquires information and exploits the uninformed proposer. The next proposition shows that a perfect equilibrium exists in which the responder captures the full trading surplus.

Proposition 3

If $\frac{2}{3}\Delta(k-1)+\frac{1}{6}(v_H-v_L)\leq c=\frac{1}{4}(v_H-v_L)-\Delta$ then in any PE the buyer gets $EU^B=0$. There exists a PE in which the buyer chooses n_B=0 and $b=\frac{1}{2}(v_H+v_L)+\Delta$ and the seller chooses n_S=0 and s=Y. Trade occurs with probability 1 and $EU^S=2\Delta$.

If the information cost is higher than the speculative profit, then the buyer is not concerned about the endogenous lemons problem. In the unique perfect equilibrium no agent acquires information, trade occurs with probability 1 and the buyer captures the full surplus. This corresponds to the standard take-it-or-leave-it-offer setting.

Proposition 4

If $c \geq \frac{1}{4}(v_H - v_L)$, then in the unique PE the buyer chooses $n_B=0$ and $b=\frac{1}{2}(v_H+v_L)-\Delta$ and the seller chooses $n_B=0$ and $s=Y$. Trade occurs with probability 1 and $EU^B=2\Delta$ and $EU^S=0$.

The last case which has not been addressed so far is the low information cost case. The next proposition shows that in a PE the buyer acquires information and a signaling game arises in which the seller also has the option to acquire information.[5] For a formal statement of α_c, β_c, γ, k and t in Proposition 5 see Step 3 Appendix A which shows that α and β depends on the information cost c.

Proposition 5

If $c<\min\{2k\Delta,\ \frac{2}{3}\Delta(k-1)+\frac{1}{6}(v_H-v_L)\}$ then a PE in mixed strategies has the following properties. The buyer chooses $n_B=1$. If $v=v_L$ the buyer chooses $b_L=v_L-\Delta+t$. If $v=v_H$ the buyer chooses $b_H=v_H-\Delta$ with probability α_c and $b_L=v_L-\Delta+t$ with probability $1-\alpha_c$. The seller chooses the following: If he sees $b=v_H-\Delta$ he chooses=Y. If the seller sees $b=v_L-\Delta+t$ he chooses $n_S=1$ with probability β_c and $n_S=0$ with probability $1-\beta_c$. If he is supposed to choose $n_S=1$, then seeing $v=v_L$ the seller chooses $s=Y$. Otherwise he chooses $s=N$. If the seller is supposed to choose $n_S=0$ then he chooses $s=Y$ with probability γ and $s=N$ with probability $1-\gamma$. Trade occurs with positive probability and $EU^B=2k\Delta-c$ and $EU^S=0$.

<u>Remark 1</u>

This paper assumes that information acquisition is observable. If information acquisition is not observable no equilibrium in pure strategies exists for $c<\frac{1}{4}(v_H-v_L)$. Yet all qualitative results may hold since a potential second mover advantage carries over to this case.

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[5] The observation that risk neutral agents may overinvest in information is related to Matthews (1984) and Hausch and Li (1993) who show that bidders acquire excessive information in pure common values auctions. Bergemann and Valimäki (2002) employs a mechanism design approach and a local efficiency concept. They show that any ex post efficient allocation mechanism causes an ex ante information acquisition inefficiency.

4. Two-Period Bargaining

The previous section shows that whether there is a first-mover or second-mover advantage in take-it-or-leave-it-offer bargaining depends on the information cost. This section extends the one-period case to two-period alternating offer bargaining and analyses the impact of the discounting of the trading surplus and the discounting of the information cost on the timing of information acquisition and trade as well as the terms-of-trade.

To focus on the interesting case, section 4 is based on the assumption that the information cost is low. Proposition 5 shows that in the one-period setting in any PE the buyer acquires information and trade occurs with positive probability and $EU^B=2k\Delta-c$ and $EU^S=0$. In order to keep the analysis tractable, two technical assumptions are made so that a full characterization of the set of PE for any $c_1\leq c_0$ and $\delta\in[0,1]$ can be given.

Assumption T1 (Bargaining technology)

The bargaining is conducted as follows. The agents submit their actions to a machine according to the following rules. The machine have entries called "$b_L(t)$" and "$b_H(t)$" for the buyer and "$s_L(t)$" and "$s_H(t)$" for the seller. (The machine sees $n_B(t)$ and $n_S(t)$.)

(1) An informed proposer is allowed to submit two different offers to the machine. An uninformed proposer is not allowed to submit state-contingent offers and must submit one offer to the machine. Both entries are filled with one number. An informed responder is allowed to submit two different responses. An uninformed responder is only allowed to submit one response. Both entries are filled with the same acceptance or rejection decision.

(2) The machine determines trade according to the following rule. Suppose the buyer is the proposer in period t. (a) Suppose $v_t=v_{tL}$. If $s_L(t)$=Y then trade occurs at the price $b_L(t)$. If $s_L(t)$=N there is no trade in period t. (b) If $v_t=v_{tH}$ then $s_H(t)$ is relevant for the determination of trade. Analogously for the case where the seller is the proposer.

Assumption T2 (Information)

(1) It is common knowledge that the quality of the asset v_t is governed by a binomial process with step $-k$ and $+k$ and with equal probability where $k>0$, i.e. in period 0 v_0 is either $v_{0L}=v-k$ or $v_{0H}=v+k$; and in period 1 v_1 is either $v_{1L}=v_0-k$ or $v_{1H}=v_0+k$. (Note, $v_{tH}-v_{tL}=2k$.)

(2) v is public information in period 0; and v_0 is public information in period 1.

(3) In period 0, if agent i chooses $n_i(0)=0$, then he knows that $E[v_0]=v$. In period 1, if he chooses $n_i(1)=0$ then he knows that $E[v_1]=v_0$. If he chooses $n_i(1)=1$, then he knows the true value v_1.

(4) If $n_i(0)=1$, then in period 0 agent i knows the true value v_0 but not the realization v_1, i.e $E_0[v_1]=v_0$. In the beginning of period 1 he is then informed about the true value v_1.

Assumption T3 (Low information cost in period 0)

$c_0<\min\{2\Delta, \frac{1}{6}(v_H-v_L), \frac{1}{4}(v_H-v_L)-\Delta\}$.

Remark 2

Assumption T1 eliminates any types of signaling. Assumption T2 eliminates a kind of "cheating". (See Remark B2 in Appendix B.) Section 5 discusses the role of these assumptions and argues that they are not crucial for the results but simplifies the analysis significantly.

Remark 3

Assumption T1 implies that k=1 in the Propositions 1 to 5. The equilibrium strategies in the Propositions 1 to 4 hold without modification. In Proposition 5 the buyer chooses $n_B=1$ and $b_L=v_L-\Delta$, $b_H\geq v_H-\Delta$ if $v=v_L$; and $b_L\geq v_L-\Delta$, $b_H=v_H-\Delta$ if $v=v_H$. The seller chooses $n_S=0$ and s=Y. In any PE trade occurs with probability 1 and $U^B=2\Delta-c$ and $U^S=0$.

Section 4.1 derives a waiting-to-invest argument in information acquisition for the delay of agreement. Section 4.2 shows that the equilibrium payoffs of the agents are non-monotonic in the discount factor of the trading surplus. Lemma 1 characterizes the continuation payoff of the seller if he does not acquire information and rejects any offer in period 0.

Lemma 1

Assumptions T1 to T3 hold. The default option D of the seller is given as follows. (i) For $\delta\leq\frac{c_1}{2\Delta}$, D=0 if $n_B(0)=0$ and $D=\delta\Delta$ if $n_B(0)=1$. (ii) For $\frac{c_1}{2\Delta}\leq\delta\leq\frac{c_1}{\Delta}$, $D=2\delta\Delta-c_1$ if $n_B(0)=0$ and $D=\delta\Delta$ if $n_B(0)=1$. (iii) For $\delta\geq\frac{c_1}{\Delta}$, $D=2\delta\Delta-c_1$.

4.1 The Delay of Agreement

Lemma 1 shows that if the buyer acquires information he may increase the default option of the seller. The intuition is simple. Given the endogenous lemons problem, if both agents are uninformed no trade occurs at all. If one agent is informed trade occurs with positive probability. In this sense actual asymmetric information is "better" than potential asymmetric information. Therefore, the information acquisition of the buyer exerts a positive externality on the seller since trade occurs with positive probability in period 1. So the default option of the seller is endogenous and depends on both the discounting and the information acquisition decision of the buyer. This section shows that if the discount factor of the trading surplus is high, no agent acquires information in period 0 and the delay of agreement occurs with probability 1.

Proposition 6

Assumptions T1 to T3 hold. If (i) $\delta>\max\{1-\frac{c_0-c_1}{2\Delta},\frac{c_1}{\Delta}\}$ or (ii) $\max\{\frac{c_1}{2\Delta},1-\frac{c_0-c_1}{\Delta},2-\frac{c_0}{\Delta}\}<\delta<\frac{c_1}{\Delta}$ then the set of PE has the following properties. No agent acquires information and no trade occurs in period 0. In period 1 the seller acquires information, trade occurs with probability 1 and $U^B=0$ and $U^S=2\delta\Delta-c_1$.

Proposition 6 shows that no PE exists in which trade occurs in period 0 although the buyer and the seller maintain symmetric information. Therefore, the delay of agreement is not caused by signaling but by an endogenous lemons problem *and* an equilibrium timing consideration of information acquisition. Since $c_0<\frac{1}{4}(v_H-v_L)-\Delta$ the endogenous lemons problem is severe so that no trade occurs in period 0 if no agent acquires information.

The intuition behind Proposition 6 (i) is as follows. Lemma 1 shows that for $\delta>\frac{c_1}{\Delta}$ the continuation payoff of the seller is $2\delta\Delta-c_1$. Therefore, the seller rejects any offer which gives him less than what he can get in period 1 and the buyer can obtain at most $2\Delta-(2\delta\Delta-c_1)$. If the remaining surplus which the buyer obtains does not cover the information cost c_0, the buyer does not acquire information. The best responses in period 0 are such that no agent acquires information. Because of the endogenous lemons problem the buyer submits a low offer which an uninformed seller does not accept. There is no asymmetric information and yet no trade occurs in period 0.

__**Remark 4**__

Rewriting the condition in Proposition 6 (i) shows that delay may occur if $2\Delta(1-\delta)<(c_0-c_1)$, i.e. if the drop in the total trading surplus is smaller than the drop in the cost of information acquisition (assuming that one agent acquires information at some time). Therefore, if information is acquired in equilibrium it is socially optimal to delay trade. This results is similar in flavor to Ingersoll and Ross (1992) who derive an optimal waiting time argument to invest under uncertainty without strategic interactions. Proposition 6 (i) proposes a kind of waiting-to-agree-result or optimal timing argument to invest in information subject to an endogenous lemons constraint.

Proposition 6 (ii) shows that although the discounting of trading surplus is not too high delay may also occur. Lemma 1 shows that for $\frac{c_1}{2\Delta}<\delta<\frac{c_1}{\Delta}$, (a) the default option of the seller is $D=2\delta\Delta-c_1$ if $n_B(0)=0$; and (b) $D=\delta\Delta>2\delta\Delta-c_1$ if $n_B(0)=1$. So if the buyer does not acquire information but provides the seller an incentive to acquire information the default option of the seller is lower but trade only occurs with probability 0.5 in period 0, because the buyer accounts for the lemons problem and $EU^B=\Delta-c_0-(\delta\Delta-c_1)$. If the buyer acquires information the default option of the seller is higher but trade occurs with probability 1 in period 0 and $U^B=2\Delta-c_0-\delta\Delta$. If both alternatives yield a negative payoff no agent acquires information. Because of the endogenous lemons problem the buyer proposes a low offer which an uninformed seller does not accept. So no trade occurs in period 0.

4.2 The Role of Discounting

Proposition 6 shows that if δ is high, a waiting-to-agree result arises and $U^B=0$ and $U^S=2\delta\Delta-c_1$. The next Proposition shows that if δ is low, an agreement in reached immediately. Given Assumption T1, Proposition 7(ai) contains Proposition 1 ($\delta=0$) as a special case.

Proposition 7

Assumptions T1 to T3 hold.

(a) If (i) $\delta<\min\{\frac{c_1}{\Delta},2-\frac{c_0}{\Delta},\frac{1}{2}\}$, (ii) $\max\{\frac{c_1}{2\Delta},\ 1-\frac{c_0-c_1}{\Delta}\}<\delta<\min\{\frac{c_1}{\Delta},2-\frac{c_0}{\Delta}\}$, or (iii) $\frac{c_1}{2\Delta}<\delta<\min\{\frac{c_1}{\Delta},1-\frac{c_0-c_1}{\Delta}\}$ and $c_1<\Delta$, then in any PE the buyer acquires information and trade occurs in period 0 and $U^B=2\Delta-c_0-\delta\Delta$ and $U^S=\delta\Delta$.

(b) If $\frac{c_1}{\Delta}<\delta<1-\frac{c_0-c_1}{2\Delta}$ then in any PE the buyer acquires information and trade occurs in period 0 and $U^B=2\Delta-c_0-2\delta\Delta+c_1$ and $U^S=2\delta\Delta-c_1$.

For other parameter constellations of c_0, c_1, and δ, endogenous outside option and endogenous lemons problem give rise to further types of equilibrium outcomes. Proposition

8 and 9 show that disagreement occurs with positive probability in period 0. Proposition 10 shows that no PE exists in which an agreement is reached in any of the two periods.

Proposition 8

Assumptions T1 to T3 hold. If $\max\{\frac{c_0}{\Delta}-1,\frac{1}{2}\}<\delta<\frac{c_1}{2\Delta}$, then set of PE has the following properties. The seller acquires information in period 0. If $v_0=v_{0L}$ trade occurs. If $v_0=v_{0H}$, there is disagreement. In period 1 trade occurs with probability 1 and $EU^B=\Delta+\delta\Delta-c_0$ and $EU^S=0$.

Proposition 8 contains two observations. (1) The buyer does not acquire information but provides the seller an incentive to acquire information in period 0. The reason is the positive externality of information acquisition. Lemma 1 shows that for $\delta<\frac{c_1}{2\Delta}$ the continuation payoff of the seller is zero, if the buyer does not acquire information in period 0. If the buyer acquires information he increases the seller's continuation payoff to $\delta\Delta$. In period 0 the buyer faces a trade-off when comparing the two alternatives. (i) If the buyer does not acquire information but provides the seller an incentive to do so, the buyer is able to keep the default option of the seller at zero but trade only occurs with probability 0.5 in period 0. His payoff is $EU^B=\Delta+\delta\Delta-c_0$. (ii) If the buyer acquires information the default option of the seller increases to $\delta\Delta$ but trade occurs with probability 1. His payoff is $U^B=2\Delta-c_0-\delta\Delta$. Proposition 8 gives conditions such that alternative (i) dominates (ii) and alternative (i) yields $EU^B>0$.

(2) The equilibrium payoff of the buyer increases in the discount factor δ of trading surplus. The intuition is as follows. In period 0 the buyer does not acquire information but provides the seller an incentive to do so. The buyer accounts for the lemons problem and trade only occurs in the low state. If there is no trade in period 0 in period 1 the seller is informed and trade occurs with probability 1 and the seller gets $2\delta\Delta$.[6] In period 0 the buyer can capture this additional surplus by proposing an appropriate offer and his expected payoff increases in δ. The seller may accept this offer since his continuation payoff is anyway zero.

[6] If the Assumptions T1 and T2 are not employed, yet trade occurs in a mixed strategies equilibrium with positive probability in period 1 so that in period 0 the buyer can capture the period 1 surplus. See also the discussion in section 5.2.

Remark 5

Proposition 8 may also hold for $c_1=c_0$. Proposition 9 and 10 complete the description of the set of PE for $c_0<\min\{2\Delta, \frac{1}{6}(v_H-v_L), \frac{1}{4}(v_H-v_L)-\Delta\}$ and any $c_1\leq c_0$ and $\delta\in[0,1]$.

Proposition 9

Assumptions T1 to T3 hold. If max $\frac{c_1}{2\Delta}<\delta<\min\{\frac{c_1}{\Delta}, 1-\frac{c_0-c_1}{\Delta}\}$ *and* $c_1>\Delta$ then the set of PE has the following properties. The seller acquires information in period 0. If $v_0=v_{0L}$ trade occurs. If $v_0=v_{0H}$, there is disagreement. In period 1 trade occurs with probability 1 and $EU^B=\Delta-c_0-\delta\Delta+c_1$ and $EU^S=2\delta\Delta-c_1$.

Proposition 10

Assumption T1 to T3 hold. If (i) $2-\frac{c_0}{\Delta}<\delta<\min\{\frac{1}{2}, \frac{c_1}{2\Delta}\}$ or (ii) $\frac{1}{2}<\delta<\min\{\frac{c_0}{\Delta}-1, \frac{c_1}{2\Delta}\}$ then no PE with trade exists.

Proposition 10 can be interpreted as saying that there exists parameter constellations such that neither the first period nor the second period proposer is able to capture enough surplus so that nobody acquires costly information. Because of the endogenous lemons problem no trade occurs at all.

5. Discussion

Section 5.1 provides some numerical examples. The driving force behind the results is that information acquisition in a common values environment exerts two effects. It can cause an endogenous lemons problem and implies that the default option D of the seller is endogenous. Section 5.2 argues that the Assumptions T1 and T2 are not crucial because dropping these assumptions only changes the exact value of D but not the qualitative implications of Proposition 6 and 8. Section 5.3 shows that the delay result may hold for T-period bargaining as well as for the case where the time interval between offers converges to zero.

5.1 Numerical Examples

Section 3 shows that the equilibrium payoff of the agents are non-monotonic in the information cost in take-it-or-leave-it-offer bargaining. If Assumption T1 is employed then k=1. Two numerical examples are illustrated in Figure 2. Graph (a) plots the equilibrium payoffs of the agents as a function of the information cost for the parameter values $\Delta=\frac{1}{20}$ and $v_H - v_L = 1$ and shows that the Propositions 5, 1, 3, and 4 arise consecutively. In Graph (b) where $\Delta=\frac{1}{8}$ and $v_H - v_L = 1$, the Propositions 5, 3 and 4 arise consecutively.

Figure 2

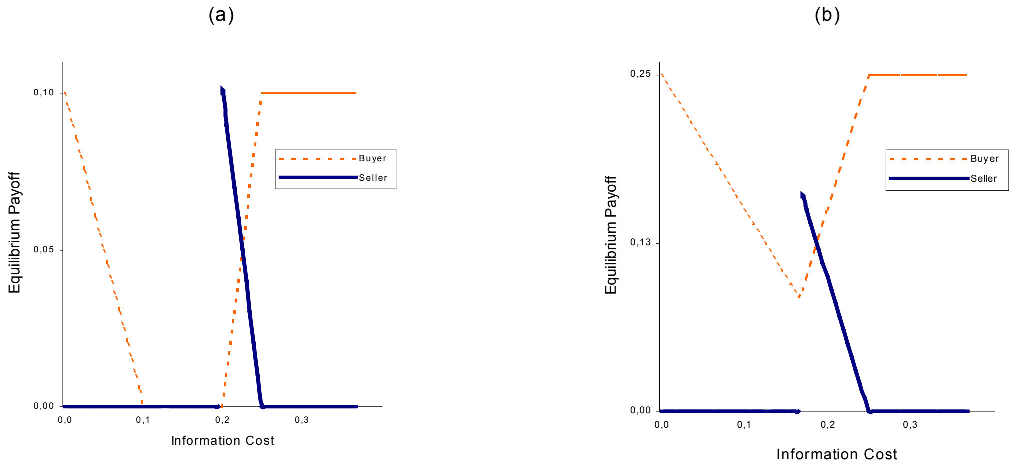

Figure 2. The equilibrium payoff of the buyer (proposer) and the seller (responder) in take-it-or-leave-it-offer bargaining is plotted as a function of the information cost for the parameter values in (a) $2\Delta=1/10$, $v_H - v_L = 1$ and (b) $2\Delta=1/4$, $v_H - v_L = 1$.

Figure 3

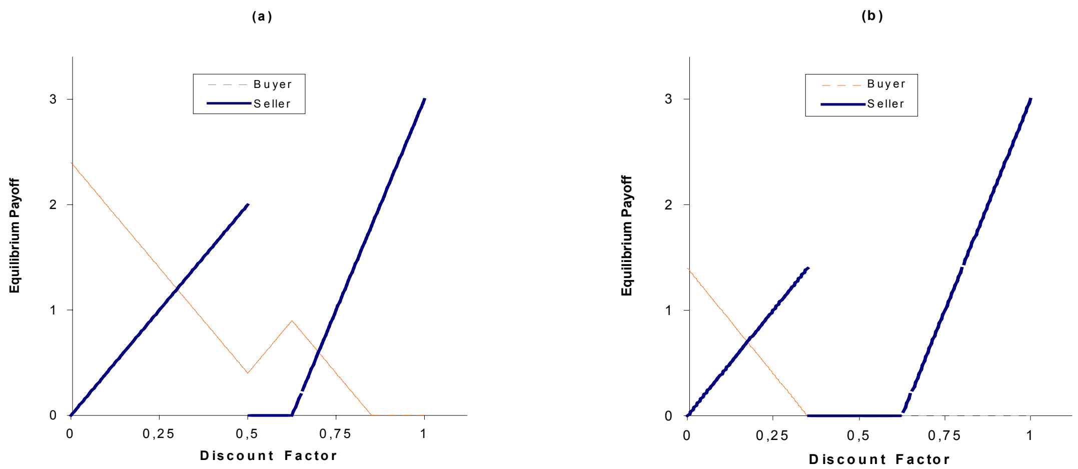

Figure 3. The equilibrium payoff of the buyer (first-period proposer) and the seller (second-period proposer) in two-period alternating-offer bargaining is plotted as a function of the discount factor of trading surplus for the parameter values in (a) $c_0=5.6$, $c_1=5$, $2\Delta=8$, and $v_H - v_L = 60$ and (b) $c_0=6.6$, $c_1=5$, $2\Delta=8$, and $v_H - v_L = 60$.

Section 4 derives a waiting-to-agree result and shows that the equilibrium payoffs are non-monotonic in the discounting of trading surplus in two period alternating offer bargaining. In Graph 3 (a) the equilibrium payoffs of the agents are plotted as a function of the discount factor for the parameter values c_0=5.6, c_1=5, Δ=4 and v_H-v_L=60 and shows that the Propositions 7, 8, 9 and 6(ii) arise consecutively. In Graph 3 (b) where c_0=6.6, c_1=5, Δ=4 and v_H-v_L=60, the Propositions 7, 10 (i,ii) and 6 (ii) arise consecutively.

5.2 The Role of The Technical Assumptions

Suppose that the Assumptions T1 and T2 are no employed for the two-period case. If the buyer acquires information, a signaling game with endogenous information acquisition arises. Assumption T1 is made to circumvent signaling in the one-period case or within the same period. Assumption T2 is made to eliminate "cheating" and signaling in the two-period case (see Remark B2 in Appendix B). These assumptions are not crucial for the waiting-to-agree result in Proposition 6 as the following argument shows. If $2\Delta_0<c_0<\frac{1}{4}(v_H-v_L)-\Delta_0$, then in no equilibrium does any agent acquire information in period 0. Because of the endogenous lemons problem the uninformed proposer submits a defensive offer which the uninformed responder rejects. So no trade arises in the standard setting, too.

These assumptions are also not crucial for Proposition 8 which states that the equilibrium payoff of the buyer (first-period proposer) increases in δ. The argument is similar. Suppose the information cost in period 1 is such that $2\delta\Delta<c_1<\frac{1}{4}(v_H-v_L)-\delta\Delta$. In period 0 the buyer has two options. (i) If the buyer does not acquire information the default option of the seller is 0. Suppose the uninformed buyer provides the seller an incentive to acquire information the buyer accounts for the endogenous lemons problem and no trade occurs in the high state in period 0. In period 1 the agents face a signaling game since the seller is informed. Denote $M_1=2k_1\delta\Delta$ (where $0.5<k_1<1$) as the maximum surplus the seller (proposer) can capture in period 1 in a perfect Bayesian equilibrium. In period 0 the buyer can propose an offer which extracts M_1. (ii) If the buyer acquires information, the default option of the seller is $2k_2\delta\Delta$ (where $0<k_2<1$) but trade may occurs with probability $p_0>0.5$ in a mixed strategy equilibrium in period 0. So the buyer compares the payoff (i) $EU^B=\Delta-c_0+2k_1\delta\Delta$ with (ii) $EU^B=p_0\cdot 2\Delta-c_0-k_2\delta\Delta$. If $\delta>(2p_0-1)/2(k_1+k_2)$, the buyer chooses the first alternative so that his expected payoff increases in δ even in the standard setting.

5.3 The Length of Bargaining

A potential difficulty in analyzing a T-period or an infinite horizon version (with or without the Assumptions T1 and T2) is that the continuation payoffs of the agents depend on the information acquisition as well as the processes $\{\Delta_t\}$and $\{c_t\}$ in a complex fashion. This section discusses some special cases and shows that the delay or waiting-to-agree-result holds for T-period and infinite horizon bargaining as well as for the case where the time interval between offers converges to zero. This section also shows that the *analysis of information acquisition* in infinite horizon bargaining reduces to a finite consideration if the discounting of the trading surplus is larger than the discounting of the information cost.

(a) Suppose that $t\in[0,1]$ is real time, and each bargaining round has a length of γ. If there is T bargaining rounds within the time interval 0 and 1, each bargaining round is of length $\gamma=1/T$. Furthermore, suppose that $\Delta_t=\delta^{\gamma\cdot t}\Delta$ for $t\in\{0,\frac{1}{T},\frac{2}{T},..,1\}$ and $c_t=\beta^{\gamma\cdot t}c$ for $t\in\{0,\frac{1}{T},\frac{2}{T},..,\frac{T-1}{T}\}$ and $c_1=\varepsilon$ where $2\Delta<c<\frac{1}{4}(v_H-v_L)-\Delta$, $\beta\geq\delta$, and ε small. It is straightforward to show that in no perfect Bayesian equilibrium does any agent acquire information at time $t<1$ or in any of the bargaining rounds 0 to $T-1$ because $c_t>2\Delta_t$. Since $c_t<\frac{1}{4}(v_H-v_L)-\Delta_t$, the uninformed proposer submits a defensive offer which the uninformed responder does not accept. So no trade occurs at time $t<1$. If $T\rightarrow\infty$, then the time interval between offers converges to zero. This argument shows that the specification of the length of single bargaining rounds is not crucial for the delay of agreement in this model. At time $t=1$ or in the final bargaining round T, information is acquired by at least one agent and trade occurs with positive probability.

(b) Suppose that T is infinite, $\Delta_t=\delta^t\Delta$, $c_t=\beta^t c$, and $c<\frac{1}{4}(v_H-v_L)-\Delta$ (for t=0,1,2,..). (i) If $2\Delta<c$ and $\delta\leq\beta$ then the agents never reach an agreement. (ii) If $2\Delta>c$ and $\delta<\beta$ then the *analysis of information acquisition* in infinite horizon bargaining reduces to a finite consideration. There exists a t^* such that $2\Delta_t<c_t$ for $t>t^*$. If no agent acquires information in any period $t<t^*$, no agreement will be reached anymore. So one can start with the backward induction argument in period t^* to determine information acquisition. However, once information is acquired, the game switches back to the infinite horizon version. Therefore, further research on this case might be of interest.

6. Conclusion

This paper analyses information acquisition in two period alternating offer bargaining where a buyer and a seller seek to agree on a price at which to trade an asset with a significant common value component (such as a financial asset).[7] This paper shows that information acquisition in such an environment can cause an endogenous lemons problem and implies that the outside options of the agents are endogenous. These two consequences give rise to a rich set of strategic considerations so that perfect equilibria may have the following properties. (1) In the one period game the agent responding to a take-it-or-leave-it-offer captures the full trading surplus. Whether there is a first or second mover advantage in ultimatum bargaining depends on the information cost. (2) If the discounting of the trading surplus is lower than the discounting of the information cost, the delay of agreement arises although in the period of disagreement the agents may maintain symmetric information. (3) The equilibrium payoffs of the agents are non-monotonic in the discount factor of the trading surplus.

Appendix A

This Appendix proves Propositions 1 to 5 together. The proof proceeds as follows. Step 1 analyses the best response correspondence of the seller to n_B=0 and b. Step 2 analyzes the buyer's payoff expectations at different triples n_B=0 and b, ensuring best responses of the seller. Step 3 analyses the best response correspondences for the case where n_B=1. Step 4 characterizes the decision of the buyer and step 5 summarizes the PE paths.

Step 1

This step analyzes the best response correspondence of the seller to n_B=0 and b. If the seller does not acquire information his strategy is denoted with $(n_S,s)=(0,s)$. If the seller acquires

[7] The article "Uncertainty prompts BT to delay bond issues" by R. Bream and A. van Duyne in the Financial Times 23 August 2000 edition reported that British Telecommunications (BT) would delay the launch of its Dollars 10bn bond deal because of uncertainty about its rating on both sides of the market. A manager of BT is quoted with "*We have deferred the bond issue because we are awaiting clarification from the rating agencies*." The authors write that "*Both S&P and Moody's Investors Service have BT's ratings on review for a likely downgrade, and investors are trying to determine how low its rating would go. BT hopes that by delaying its deal investors will know the full extend of any agency move before deciding whether to buy bonds, therefore securing more accurate pricing*." Instead of writing a complete contract which specifies the interest rate as function of the rating decision, BT decided for the delay of the take-it-or-leave-it-offer of the bond issue.

information his strategy is denoted with $(n_S,s_L,s_H)=(1,s_L,s_H)$ where s_L and s_H denote his responses when seeing $v=v_L$ and $v=v_H$, respectively.

<u>Step 1a</u>

<u>Case 1</u>: If $b \le v_L-\Delta$, then the seller never wants to sell, so he has nothing to gain from buying information. The best response to $(0,b)$ with $b \le v_L-\Delta$ is given by $(0,s)$ where $s=N$.

<u>Case 2</u>: Suppose $v_L-\Delta<b<\frac{1}{2}(v_H+v_L)-\Delta$. (a) If the seller acquires no information, he can only loose from trading, so $(0,s)$ with $s=Y$ is a dominated choice. His maximal payoff without information acquisition is therefore $EU^S=0$. (b) If the seller buys information, then he will choose $s_H=N$ if $v=v_H$; and $s_L=Y$ if $v=v_L$. His maximal expected payoff with information acquisition is $EU^S=\frac{1}{2}[b-(v_L-\Delta)]-c$.

Consequently, if $\frac{1}{2}(b-v_L+\Delta)-c<0$, the best response of the seller to $(0,b)$ where $v_L-\Delta<b<\frac{1}{2}(v_H+v_L)-\Delta$ is given by $(0,s)$ with $s=N$. If $\frac{1}{2}(b-v_L+\Delta)-c>0$, the best response of the seller to $(0,b)$ where $v_L-\Delta<b<\frac{1}{2}(v_H+v_L)-\Delta$ is given by $(1,s_L,s_H)$ with $s_L=Y$ and $s_H=N$. If $\frac{1}{2}(b-v_L+\Delta)-c=0$, the set of best responses of the seller is given by $(0,s)$ with $s=N$ and $(1,s_L,s_H)$ with $s_L=Y$ and $s_H=N$.

<u>Case 3</u>: Suppose $b=\frac{1}{2}(v_H+v_L)-\Delta$. The same argument shows that if $\frac{1}{2}(b-v_L+\Delta)-c<0$ the set of best response of the seller is given by $(0,s)$ with $s=N$ and $(0,s)$ with $s=Y$. If $\frac{1}{2}(b-v_L+\Delta)-c>0$, then as before, the best response of the seller is given by $(1,s_L,s_H)$ with $s_L=Y$ and $s_H=N$. If $\frac{1}{2}(b-v_L+\Delta)-c=0$, then the set of best responses of the seller is given by $(0,s)$ with $s=Y$, $(0,s)$ with $s=N$, and $(1,s_L,s_H)$ with $s_L=Y$ and $s_H=N$.

<u>Case 4</u>: Suppose $\frac{1}{2}(v_H+v_L)-\Delta<b<v_H-\Delta$. (a) If the seller acquires no information, he chooses $s=Y$. His expected payoff is $EU^S=b-\frac{1}{2}(v_H+v_L)+\Delta$. (b) If the seller buys information, then he chooses $s_L=Y$ and $s_H=N$. His maximal expected payoff with information acquisition is $EU^S=\frac{1}{2}[b-(v_L-\Delta)]-c$, as before.

It follows that if $\frac{1}{2}(b-v_L+\Delta)-c<b-\frac{1}{2}(v_H+v_L)+\Delta$, the best response of the seller to $(0,b,b)$ with $\frac{1}{2}(v_H+v_L)-\Delta<b<v_H-\Delta$ is given by $(0,s)$ with $s=Y$. If $\frac{1}{2}(b-v_L+\Delta)-c>b-\frac{1}{2}(v_H+v_L)+\Delta$, the best response of the seller to $(0,b)$ with $\frac{1}{2}(v_H+v_L)-\Delta<b<v_H-\Delta$ is given by $(1,s_L,s_H)$ with $s_L=Y$ and $s_H=N$. Otherwise the seller is indifferent between the two responses.

<u>Case 5</u>: Suppose $b=v_H-\Delta$. (a) If the seller does buy information, he chooses $s_L=Y$ and he is willing to set $s_H=Y$, allowing a trade to occur albeit without any net gain to himself. His

expected payoff is $EU^S = \frac{1}{2}(b-v_L+\Delta)+\frac{1}{2}(b-v_H+\Delta)-c = b-\frac{1}{2}(v_L+v_H)+\Delta-c$. (b) If the seller does not acquire information, then he chooses s=Y and $EU^S=b-\frac{1}{2}(v_L+v_H)+\Delta$. Consequently, buying information is dominated by not buying information. The seller's best response to (0,b) with $b=v_H-\Delta$ is to choose (0,s) with s=Y.

Case 6: Suppose $b>v_H-\Delta$. The same argument as in case 5 shows that the seller's best response to (0,b) with $b>v_H-\Delta$ is to choose (0,s) with s=Y.

Step 1b

The preceding discussion has not yet gone into much detail about the seller's information acquisition decision. In case 1, 5, and 6 the information acquisition best response of the seller is not to acquire information. Only if $v_L-\Delta<b<v_H-\Delta$, it is potentially worthwhile for the seller to acquire information. In case 2 and 3, the information acquisition decision turns on whether

(1) $\frac{1}{2}(b-v_L+\Delta)-c <=> 0,$

in case 4 on whether

(2) $\frac{1}{2}(b-v_L+\Delta)-c <=> b-\frac{1}{2}(v_H+v_L)+\Delta.$

Given that the left-hand side of (1) is increasing in b and the difference between the left-hand side and the right-hand side of (2) is decreasing in b, information acquisition is attractive at any price b if and only if it is attractive at $b=\frac{1}{2}(v_H+v_L)-\Delta$, the upper bound of the interval defining Cases 2 and 3 and the lower bound of the interval defining Case 4. Substituting $b=\frac{1}{2}(v_H+v_L)-\Delta$ into the left-hand side of (2) yield $(v_H-v_L)/4-c$. Thus there are three possibilities.

Alternative I: $c>\frac{1}{4}(v_H-v_L)$.

In this case, at $b=\frac{1}{2}(v_H+v_L)-\Delta$, information acquisition is not worthwhile, i.e.

$\frac{1}{2}[\frac{1}{2}(v_H+v_L)-\Delta-v_L+\Delta]-c=\frac{1}{4}(v_H-v_L)-c < 0$

and

$\frac{1}{4}(v_H+v_L)-c < \frac{1}{2}(v_H+v_L)-\Delta-\frac{1}{2}(v_H+v_L)+\Delta.$

So if $c>\frac{1}{4}(v_H-v_L)$, then information acquisition is not worthwhile to the seller regardless of what price he expects the uninformed buyer to set. The seller's best response to (0,b) is to choose (0,s) where (i) s=N if $b<\frac{1}{2}(v_H+v_L)-\Delta$, (ii) s=Y or s=N if $b=\frac{1}{2}(v_H+v_L)-\Delta$, and (iii) s=Y if $b>\frac{1}{2}(v_H+v_L)-\Delta$.

Alternative II: $c<\frac{1}{4}(v_H-v_L)$.

In this case, at $b=\frac{1}{2}(v_H+v_L)-\Delta$, information acquisition is worthwhile, i.e.

$$\frac{1}{2}[\frac{1}{2}(v_H+v_L)-\Delta-v_L+\Delta]-c=\frac{1}{4}(v_H-v_L)-c>0$$

and

$$\frac{1}{4}(v_H+v_L)-c>\frac{1}{2}(v_H+v_L)-\Delta-\frac{1}{2}(v_H+v_L)+\Delta.$$

Denote $\underline{b}$ as the price where the left-hand side of (1) is just zero and $\bar{b}$ where the left-hand side equals the right-hand side of (2). There exist critical prices

$$\underline{b}=v_L-\Delta+2c<\frac{1}{2}(v_H+v_L)-\Delta,$$

and

$$\bar{b}=v_H-\Delta-2c>\frac{1}{2}(v_H+v_L)-\Delta,$$

such that information acquisition is not worthwhile to the seller if the buyer sets $b<\underline{b}$ or $b>\bar{b}$. If the buyer sets $b\in(\underline{b},\bar{b})$, then it is worthwhile to the seller to acquire information. (At $\underline{b}$ and $\bar{b}$, the seller is indifferent.)

(i) The seller's best response to (0,b) with $b<\underline{b}$ or $b>\bar{b}$ is to choose (0,s) where s=N if $b<\underline{b}$ and s=Y if $b>\bar{b}$. (ii) The seller's best response to (0,b) with $b\in(\underline{b},\bar{b})$, is to choose $(1,s_L,s_H)$ with s_L=Y and s_H=N. (iii) For $b=\underline{b}$, the seller is indifferent between (0,s) with s=N and $(1,s_L,s_H)$ with s_L=Y and s_H=N. (iv) For $b=\bar{b}$, the seller is indifferent between (0,s) with s=N and $(1,s_L,s_H)$ with s_L=Y and s_H=N.

Alternative III: $c=\frac{1}{4}(v_H-v_L)$.

This is the boundary between Alternatives I and II. For $b=\frac{1}{2}(v_H+v_L)-\Delta$, the seller is indifferent between (0,s) with s=Y, (0,s) with s=Y, and $(1,s_L,s_H)$ with s_L=Y and s_H=N. For

$b \neq \frac{1}{2}(v_H+v_L)-\Delta$, the best response of the seller is to choose (0,s) where s=N if $b<\frac{1}{2}(v_H+v_L)-\Delta$, and s=Y if $b>\frac{1}{2}(v_H+v_L)-\Delta$.

<u>Step 2</u>

This step analyses the buyer's payoff expectations at triples (0,b) ensuring best responses of the seller.

<u>Alternative I</u>: $c>\frac{1}{4}(v_H-v_L)$.

As mentioned, the seller's best response correspondence to (0,b) is to choose (0,s) where (i) s=N if $b<\frac{1}{2}(v_H+v_L)-\Delta$, (ii) s=Y or s=N if $b=\frac{1}{2}(v_H+v_L)-\Delta$, and (iii) s=Y if $b>\frac{1}{2}(v_H+v_L)-\Delta$. The buyers' payoff is zero if $b<\frac{1}{2}(v_H+v_L)-\Delta$ or if $b=\frac{1}{2}(v_H+v_L)-\Delta$ and s=N. The buyer's payoff is $EU^B=\frac{1}{2}(v_L+v_H)+\Delta-b$ if $b=\frac{1}{2}(v_H+v_L)-\Delta$ and s=Y or $b>\frac{1}{2}(v_H+v_L)-\Delta$.

Thus, by setting $b=\frac{1}{2}(v_L+v_H)$, the buyer can ensure himself the payoff Δ. All (0,b) with $b<\frac{1}{2}(v_H+v_L)-\Delta$ provides the buyer with a lower payoff than (0,b) with $b=\frac{1}{2}(v_H+v_L)$). Similarly, all triples (0,b) with $b>\frac{1}{2}(v_H+v_L)-\Delta$ provides the buyer with a worse payoff than the triple (0,b') where $\frac{1}{2}(v_H+v_L)-\Delta<b'<b$.

The only strategy without information acquisition of the buyer which is a candidate for being best response to a subform perfect strategy of the seller is thus given by the triple (0,b) with $b=\frac{1}{2}(v_H+v_L)-\Delta$. However, if this is to be best response of the buyer, it must be the case, that the seller's response to this choice is to set (0,s) with s=Y, i.e. the seller must resolve his indifference by opting for trade. In this case $EU^B=2\Delta$.

<u>Remark A1</u>

This line of arguments will be used repeatedly to establish (the existence of) best responses of the agents. Otherwise the proposer has no best responses. (See Fudenberg and Tirole (1998, p.116).) The subsequent steps assume that an indifferent responder chooses a response from his set of best responses which the proposer prefers most.

<u>Alternative II</u>: $c<\frac{1}{4}(v_H-v_L)$.

Case 1 and 2a: (i) If the buyer chooses (0,b) with $b<\underline{b}=v_L-\Delta+2c$, the seller chooses (0,s) with s=N. (ii) If the buyer chooses (0,b) with $b=\underline{b}$, the seller is indifferent between (0,s) and s=N and $(1,s_L,s_H)$ with s_L=Y and s_H=N. Depending on which alternative the seller chooses, the buyer's payoff is $EU^B=0$ or $EU^B=\frac{1}{2}(v_L+\Delta-\underline{b})=\Delta-c$.

Case 2b, 3, 4a: (i) If the buyer chooses (0,b) with $\underline{b}=v_L-\Delta+2c<b<\overline{b}=v_H-\Delta-2c$, the seller chooses $(1,s_L,s_H)$ with s_L=Y and s_H=N and $EU^B=\frac{1}{2}(v_L+\Delta-b)$. (ii) If the buyer chooses (0,b) with $b=\overline{b}$, the seller is indifferent between choosing (0,s) with s=Y and $(1,s_L,s_H)$ with s_L=Y and s_H=N. If the seller chooses the first alternative, then $EU^B=\frac{1}{2}(v_L+v_H)+\Delta-\overline{b}=\frac{1}{2}(v_L+v_H)+\Delta-(v_H-\Delta-2c)=2\Delta+2c-\frac{1}{2}(v_H-v_L)$. If the seller chooses the second alternative, then $EU^B=\frac{1}{2}(v_L+\Delta-\overline{b})=\Delta+c-\frac{1}{2}(v_H-v_L) < 2\Delta+2c-\frac{1}{2}(v_H-v_L)$. So the buyer has a strict preference to have the seller resolve his indifference by not acquiring information.

Case 4b, 5, 6: If the buyer chooses (0,b) with $b>\overline{b}=v_H-\Delta-2c$, the seller chooses (0,s) where s=Y and $EU^B=\frac{1}{2}(v_L+v_H)+\Delta-b < 2\Delta+2c-\frac{1}{2}(v_H-v_L)$.

Given these observations, any choice (0,b) with $b>\overline{b}$ is obviously worse for the buyer than the choice (0,b) with $b=\frac{1}{2}(b+\overline{b})$. Similarly, any choice (0,b) with $\underline{b}<b<\overline{b}$ is worse for the buyer than (0,b) with $b=\frac{1}{2}(b+\underline{b})$; as is the choice (0,b) with $b=\overline{b}$ followed by information acquisition of the seller, i.e. $(1,s_L,s_H)$ with s_L=Y and s_H=N.

The only strategies without information acquisition of the buyer which remain as possible candidates for being best responses to a subform perfect strategy of the seller are the following: (i) (0,b) with $b=\overline{b}$, assuming that this is followed by the seller choosing (0,s) with s=Y, (ii) (0,b) with $b=\underline{b}$, assuming that this is followed by $(1,s_L,s_H)$ with s_L=Y and s_H=N, (iii) (0,b) with $b<\underline{b}$, followed by (0,s) where s=N. Path (i) implies $EU^B=2\Delta+2c-\frac{1}{2}(v_H-v_L)$, path (ii) implies $EU^B=\Delta-c$, and path (iii) implies no trade and $EU^B=0$.

<u>Alternative III</u>: $c=\frac{1}{4}(v_H-v_L)$.

Based on an analogous argument as above, the only strategy without information acquisition of the buyer which is a candidate for being best response to a subform perfect strategy of the seller is given by (0,b) with $b=\frac{1}{2}(v_H+v_L)-\Delta$, assuming that the indifferent seller chooses (0,s) with s=Y. Then $EU^B=2\Delta$ and $EU^S=0$.

Step 3

This step analyses the case where $n_B=1$.

(a) The following argument shows that no best responses in pure strategies exist. Suppose the informed buyer is honest and chooses $b=v_L-\Delta$ if $v=v_L$ and $b=v_H-\Delta$ if $v=v_H$. In this case the seller is willing to choose s=Y. However, if the seller always chooses s=Y, the buyer has an incentive to choose $b=v_L-\Delta$. (If the seller always choose s=N when seeing $b<v_H-\Delta$ then the buyer always chooses $b=v_H-\Delta$ if $v=v_H$. In this case seeing $b=v_L-\Delta$ is fully revealing and the seller may choose s=Y). So no best responses in pure strategies exists.

(b) It is easy to see that choosing s=Y when seeing $b=v_L-\Delta$ is a weakly dominated strategy. The seller never gets some surplus but may suffer a lemons problem.

(c) Define $b_L=v_L-\Delta+t$ for $0<t\leq 2\Delta$ and $b_H=v_H-\Delta$. (Note, the informed buyer would not choose $b>v_L+\Delta$ at $v=v_L$. So any $b>v_L+\Delta$ reveals that $v\neq v_L$.)

(d) Best responses of both agents are obtained by construction.

Step 3a

(1) Suppose the buyer considers the following strategies. If the buyer sees $v=v_H$ then he chooses $b=b_H$ with probability α and $b=b_L$ with probability $1-\alpha$. If he sees $v=v_L$ then he chooses $b=b_L$.

(2) Suppose the seller considers the following strategies. If the seller sees $b=b_H$ he chooses s=Y. If he sees $b=b_L$ two cases arises. (a) If $t\geq 2c$ he may choose $n_S=1$ with probability β, and $n_S=0$ with probability $1-\beta$. If he is supposed to choose $n_S=1$ then seeing $v=v_L$ he chooses s=Y; and seeing $v=v_H$ he chooses s=N. If he is supposed to choose $n_S=0$ then he chooses s=Y with probability γ and s=N with probability $1-\gamma$. (b) If $t<2c$, he chooses $n_S=0$ and s=Y with probability γ and s=N with probability $1-\gamma$.

Step 3b (Making the buyer indifferent at $v=v_H$)

(1) Suppose the seller chooses $n_S=0$. If $v=v_H$ and if the buyer chooses $b=b_H$ then his payoff is $U^B=2\Delta$. The buyer is indifferent between choosing $b=b_L$ and $b=b_H$ at $v=v_H$ if $EU^B=\gamma[v_H+\Delta-(v_L-\Delta+t)]=2\Delta$. (Note, c is sunk at the offer stage.) In order to make the buyer indifferent the seller chooses $\gamma=2\Delta/(v_H-v_L+2\Delta-t)$.

(2) Suppose the seller chooses $n_S=1$ with probability β and $n_S=0$ with probability $1-\beta$. The buyer is indifferent between choosing $b=b_L$ and $b=b_H$ at $v=v_H$ if $EU^B=\beta[v_L+\Delta-(v_L-\Delta+t)]+(1-\beta)[\gamma(v_H+\Delta-(v_L-\Delta+t))]=2\Delta \Leftrightarrow \beta[2\Delta-t]-\beta[\gamma(v_H-v_L+2\Delta-t)]=2\Delta$

$-\gamma(v_H-v_L+2\Delta-t)$. In order to make the buyer indifferent the seller chooses $\beta=(2\Delta-\gamma(v_H-v_L+2\Delta-t))/(2\Delta-t-\gamma(v_H-v_L+2\Delta-t))$.

Step 3c (Making the seller indifferent when seeing $b=b_L$)

Case 1: $t<2c$.

The seller never chooses $n_S=1$; see Case 2. If the uninformed seller sees $b=b_L$ and if he chooses $s=Y$ then $EU^S=\frac{1}{2}[(v_L-\Delta+t-(v_L-\Delta)]+\frac{1}{2}\alpha_0[(v_L-\Delta+t-(v_H-\Delta)]=\frac{1}{2}t+\frac{1}{2}\alpha_0(v_L-v_H+t)$. If the seller chooses $s=N$ then $U^S=0$. In order to make the seller indifferent the buyer chooses $\alpha_0=t/(v_H-v_L-t)$.

Case 2: $t\geq 2c$.

The seller may choose $n_S=1$. If the seller chooses $n_S=1$ and sees $v=v_L$ then he chooses $s=Y$. Otherwise he chooses $s=N$. $EU^S=\frac{1}{2}[v_L-\Delta+t-(v_L-\Delta)]-c=\frac{1}{2}t-c$. If the seller chooses $n_S=0$ then $EU^S=\frac{1}{2}t+\frac{1}{2}\alpha_1(v_L-v_H+t)$. The seller is indifferent between $n_S=0$ and $n_S=1$ if $\frac{1}{2}t-c=\frac{1}{2}t+\frac{1}{2}\alpha_1(v_L-v_H+t)$. In order to make the seller indifferent the buyer chooses $\alpha_1=c/(v_H-v_L-t)$.

Step 3d (The decision of an informed buyer)

Case 1: $t<2c$.

The expected payoff of the buyer (before information acquisition) is

$$EU^B=\tfrac{1}{2}\gamma[(v_L+\Delta-(v_L-\Delta+t)]+\tfrac{1}{2}[(1-\alpha_0)(v_H+\Delta-(v_H-\Delta))+\alpha_0\gamma(v_H+\Delta-(v_L-\Delta+t))]-c.$$

$$EU^B=\tfrac{1}{2}\gamma[2\Delta-t]+\tfrac{1}{2}[(1-\alpha_0)2\Delta+\alpha_0\gamma(v_H-v_L+2\Delta-t)]-c.$$

$$EU^B=\tfrac{1}{2}\gamma[2\Delta-t]+\Delta-\alpha_0\Delta+\tfrac{1}{2}\alpha_0\gamma(v_H-v_L+2\Delta-t)-c.$$

$$EU^B=\Delta+\Delta(2\Delta-t)/(v_H-v_L+2\Delta-t)-c.$$

The buyer chooses $t\in(0,2\Delta)$ to maximizes his payoff and therefore,

$$t_0^*=\tfrac{1}{2}(-v_H+v_L-\Delta)+\sqrt{\tfrac{1}{4}(-v_H+v_L-\Delta)^2-\Delta\cdot(-v_H+v_L-\Delta)}>0\,.$$

Define k_0 such that $2k_0\Delta=\Delta+\Delta(2\Delta-t)/(v_H-v_L+2\Delta-t)$ then

$$k_0=\tfrac{1}{2}+(\Delta-0.5t_0^*)/(v_H-v_L+2\Delta-t_0^*)\,.$$

Case 1: $t\geq 2c$.

The expected payoff of the buyer (before information acquisition) is

$EU^B=\frac{1}{2}[(\beta+(1-\beta)\gamma[(v_L+\Delta-(v_L-\Delta+t)]+\frac{1}{2}[(1-\alpha)(v_H+\Delta-(v_H-\Delta))+\alpha(1-\beta)\gamma(v_H+\Delta-(v_L-\Delta+t))]-c$

Define $t_1^*\in\underset{t\in(0,2\Delta)}{\operatorname{argmax}}=EU^B$ and k_1 such that $2k_1\Delta=EU^B(t_1^*)$.

Consequently, there exists a critical c' such that if c>c' the buyer chooses t_0^* and α_0. If c<c' then the buyer chooses t_1^* and α_1. If c=c' then the buyer is indifferent between the two alternatives. The payoff of the buyer is $EU^B=2k\Delta-c$ where $k\in(\frac{1}{2},1)$ and $k=\max[k_0, k_1]$.

Step 4 (The buyer's decision)

Alternative I: $c>\frac{1}{4}(v_H-v_L)$.

It is easy to see that the best response of the buyer is to choose (0,b) with $b=\frac{1}{2}(v_H+v_L)-\Delta$, assuming that this is followed by (0,s) with s=Y. Trade occurs with probability 1 and $EU^B=2\Delta$ and $EU^S=0$.

Alternative II: $c=\frac{1}{4}(v_H-v_L)$.

As above, the best response of the buyer is to choose (0,b) with $b=\frac{1}{2}(v_H+v_L)-\Delta$, assuming that this is followed by (0,s) with s=Y and $EU^B=2\Delta$ and $EU^S=0$.

Alternative III: $c<\frac{1}{4}(v_H-v_L)$.

The set of candidates without information acquisition for being best responses is the following: (a) (0,b) with $b=v_H-\Delta-2c$ assuming it is followed by (0,s) with s=Y. (b) (0,b) with $b=v_L-\Delta+2c$ assuming it is followed by $(1,s_L,s_H)$ with $s_L=Y$ and $s_H=N$. (c) (0,b) where $b<v_L-\Delta+2c$, followed by (0,s) with s=N. A candidate with information acquisition for being best responses is the following (d) $(1,b_L,b_H)$ where the buyer randomizes over $b_L=v_L-\Delta+t$ and $b_H=v_H-\Delta$, assuming it is followed by (0,s) where the seller randomizes over s=Y and s=N. The buyer's expected payoff of the various strategies are given as follows: (a) $2\Delta+2c-\frac{1}{2}(v_H-v_L)$, (b) $\Delta-c$, (c) 0, and (d) $2k\Delta-c$. (Since $k>\frac{1}{2}$, strategy (d) dominates strategy (b)).

Case 1: $c>\frac{2}{3}\Delta(k-1)+\frac{1}{6}(v_H-v_L)$.

Strategy (a) dominates strategy (d). So the buyer compares strategy (a) with (c). If $c<\frac{1}{4}(v_H-v_L)-\Delta$, the buyer chooses strategy (c). If $c>\frac{1}{4}(v_H-v_L)-\Delta$, the buyer chooses strategy (a). If $c=\frac{1}{4}(v_H-v_L)-\Delta$, the buyer is indifferent between the two choices.

Case 2: $c<\frac{2}{3}\Delta(k-1)+\frac{1}{6}(v_H-v_L)$.

Strategy (d) dominates (a). The buyer compares strategy (d) with (c). If $c>2k\Delta$ the buyer the buyer chooses strategy (a). If $c<2k\Delta$, the buyer chooses (d). If $c=2k\Delta$ the buyer the buyer is indifferent between the two strategies.

Case 3: $c=\frac{2}{3}\Delta(k-1)+\frac{1}{6}(v_H-v_L)$.

The buyer is indifferent between strategy (a) and (d). So the buyer compares (a,d) with (c). If $c>2k\Delta$ the buyer chooses (c). If $c<2k\Delta$, the buyer is indifferent between the alternatives (a) and (d). If $c=2k\Delta$ the buyer the buyer is indifferent between the three strategies.

Step 5 (Equilibrium paths)

If $c<\min\{2k\Delta, \frac{2}{3}\Delta(k-1)+\frac{1}{6}(v_H-v_L)\}$ then a PE in mixed strategies has the following properties. The buyer chooses $n_B=1$. If $v=v_L$ the buyer chooses $b_L=v_L-\Delta+t$. If $v=v_H$ the buyer chooses $b_H=v_H-\Delta$ with probability α_c and $b_L=v_L-\Delta+t$ with probability $1-\alpha_c$. The seller chooses the following: If he sees $b=v_H-\Delta$ he chooses=Y. If the seller sees $b=v_L-\Delta+t$ he chooses $n_S=1$ with probability β_c and $n_S=0$ with probability $1-\beta_c$. If he is supposed to choose $n_S=1$, then seeing $v=v_L$ the seller chooses s=Y. Otherwise he chooses s=N. If the seller is supposed to choose $n_S=0$ then he chooses s=Y with probability γ and s=N with probability $1-\gamma$. Trade occurs with positive probability and $EU^B=2k\Delta-c$ and $EU^S=0$. (*Proposition 5*)

If $2k\Delta<c<\frac{1}{4}(v_H-v_L)-\Delta$ then the set of SPE is given as follows. The buyer chooses (0,b) with $b<v_L-\Delta+2c$ and the seller chooses (0,s) with s=N. There is no SPE with trade. (*Proposition 1*)

If $\max\{\frac{2}{3}\Delta(k-1)+\frac{1}{6}(v_H-v_L), \frac{1}{4}(v_H-v_L)-\Delta\}<c<\frac{1}{4}(v_H-v_L)$ then in the unique PE the buyer chooses (0,b) with $b=v_H-\Delta-2c$ and the seller chooses (0,s) with s=Y. Trade occurs with probability 1 and $EU^B=2\Delta+2c-\frac{1}{2}(v_H-v_L)$ and $EU^S=\frac{1}{2}(v_H-v_L)-2c$. (The buyer chooses this strategy if $\frac{2}{3}\Delta(k-1)+\frac{1}{6}(v_H-v_L)<c<\min\{2k\Delta,\frac{1}{4}(v_H-v_L)\}$ or $\max\{2k\Delta,\frac{1}{4}(v_H-v_L)-\Delta\}<c<\frac{1}{4}(v_H-v_L)$.) (*Proposition 2*)

If $\frac{2}{3}\Delta(k-1)+\frac{1}{6}(v_H-v_L)\le c=\frac{1}{4}(v_H-v_L)-\Delta$, then two types of PE exist. (i) The buyer chooses (0,b) with $b<v_L-\Delta+2c$ and the seller chooses (0,s) with s=N. No trade occurs. (ii) The buyer chooses (0,b) with $b=v_H-\Delta-2c=\frac{1}{2}(v_H+v_L)+\Delta$ and the seller chooses (0,s) with s=Y. Trade occurs with probability 1 and $EU^B=0$ and $EU^S=\frac{1}{2}(v_H-v_L)-2c=2\Delta$. (*Proposition 3*)

If $c \geq \frac{1}{4}(v_H - v_L)$, then in the unique PE the buyer chooses (0,b) with $b=\frac{1}{2}(v_H+v_L)-\Delta$ and the seller chooses (0,s) with s=Y. Trade occurs with probability 1 and $EU^B=2\Delta$ and $EU^S=0$. (*Proposition 4*) **QED**

Appendix B

Remark B 1

(a) Given Assumption T1, the following arguments show that for Proposition 1 to 5 k=1. Define $\hat{b}_L \equiv v_L - \Delta$ and $\hat{b}_H \equiv v_H - \Delta$. It is easy to see that the best responses of the seller are given as follows. (i) If $b_L = \hat{b}_L$ and $b_H = \hat{b}_H$ then the seller is indifferent between s=Y and s=N. (ii) If $b_L = \hat{b}_L$ and $b_H > \hat{b}_H$ or $b_L > \hat{b}_L$ and $b_H = \hat{b}_H$ or $b_L > \hat{b}_L$ and $b_H > \hat{b}_H$ then the seller's (weakly) best response is to choose s=Y. (iii) If $b_L < \hat{b}_L$ and $b_H \geq \hat{b}_H$ or $b_L \geq \hat{b}_L$ and $b_H < \hat{b}_H$ then the seller chooses s=N. In any cases $EU^S \geq 0$.

(b) It is easy to see that a best response of the informed buyer is to choose $b_L=v_L-\Delta$ and $b_H=v_H-\Delta$, assuming the indifferent seller opts for trade. The buyer gets $U^B=2\Delta-c$ and $U^B=0$. However, the set of best responses is larger. If $v=v_L$, the buyer can choose $b_L=v_L-\Delta$ and any $b_H \geq v_H-\Delta$. If $v=v_H$, the buyer can choose any $b_L \geq v_L-\Delta$ and $b_H=v_H-\Delta$.

The remainder of Appendix B is organized as follows. Lemma 1 is proven first which describes best responses in period 1 for the cases (i) $n_S(0)=0$ and $n_B(0)=0$ and (ii) $n_S(0)=0$ and $n_B(0)=1$. Then the Propositions 6 to 10 are proven together. It is assumed that $c_0<\min\{2\Delta, \frac{1}{6}(v_H-v_L), \frac{1}{4}(v_H-v_L)-\Delta\}$. Since $v_{tH}-v_{tL}=v_H-v_L$ for all t, the time subscript is dropped for this expression.

Proof of Lemma 1 (Best responses in period 1)

Case 1 : $n_S(0)=n_B(0)=0$.

The situation is analogous to the one-period case. In period 1 the seller is the proposer and the buyer is the responder. (Note, $c_1 \leq c_0$ and $\Delta_1=\delta\Delta \leq \Delta_0$.)

If $\delta > \frac{c_1}{2\Delta}$ then $c_1<\min\{2\Delta_1, \frac{1}{6}(v_H-v_L), \frac{1}{4}(v_H-v_L)-\Delta_1\}$. Analogous to Proposition 1, a pair of best responses in this subgame is given as follows. The seller chooses $n_S(1)=1$,

$s_L(1)=v_{1L}+\delta\Delta$ and $s_H(1)=v_{1H}+\delta\Delta$ and the indifferent buyer chooses $n_B(1)=0$, $b(1)=Y$. Trade occurs with probability 1. The continuation payoff of the seller is $U^S=2\delta\Delta-c_1$.

If $\delta<\frac{c_1}{2\Delta}$ then $2\Delta_1<c_1<\min\{\frac{1}{6}(v_H-v_L), \frac{1}{4}(v_H-v_L)-\Delta_1\}$. Analogous to Proposition 2, the best responses in this subgame imply no trade. The continuation payoff is $U^S=0$.

If $\delta=\frac{c_1}{2\Delta}$ then the seller's continuation payoff is $EU^S=0$.

<u>Case 2</u>: Suppose $n_S(0)=0$ and $n_B(0)=1$.

Given Assumption T2, the seller does not learn anything about v_1 from observing $b_L(0)$ and $b_H(0)$. Since v_0 is public information in period 1 an uninformed seller knows that v_1 is either $v_{1L}=v_0-k$ or $v_{1H}=v_0+k$. The seller compares the following alternatives.

(i) If $n_S(1)=0$, then the uninformed seller accounts for the lemons problem and chooses $s(1)=v_{1H}+\delta\Delta$. Trade occurs with probability 0.5, assuming that the indifferent buyer opts for partial trade and chooses $b_L(1)=N$ and $b_H(1)=Y$. The seller's continuation payoff is $EU^S=\delta\Delta$. (Note, if $s(1)=v_{1L}+\delta\Delta$ trade may occur with probability 1 but the seller obtains $EU^S=2\delta\Delta-(v_H-v_L)/2<0$ since $\Delta<(v_H-v_L)/4$.)

(ii) If $n_S(1)=1$, then the seller chooses $s_L(1)=v_L+\delta\Delta$ and $s_H(1)=v_H+\delta\Delta$. Assuming that the indifferent informed buyer opts for trade and chooses $b_L(1)=Y$ and $b_H(1)=Y$, the seller gets $EU^S=2\delta\Delta-c_1$.

So if $2\delta\Delta-c_1>\delta\Delta$, i.e. $\delta>\frac{c_1}{\Delta}$, then the seller acquires information and his continuation payoff is $EU^S=2\delta\Delta-c_1$. If $\delta<\frac{c_1}{\Delta}$, then the seller acquires no information and his continuation payoff is $EU^S=\delta\Delta$. If $\delta=\frac{c_1}{\Delta}$, then the seller is indifferent between the two alternatives.

<u>Remark B2</u>

Assumption T2 is employed to rule out the following considerations. Suppose the quality is a random variable and the informed buyer tries to confuse the seller by offering more than the outside option D to the seller. For example, if $\delta\leq\frac{c_1}{\Delta}$ and $n_B(0)=1$ then $D=\delta\Delta$. Suppose $b_L(0)=v_L-\Delta+\delta\Delta$ and $b_H(0)=v_H-\Delta+\delta\Delta+\varepsilon$. How should the seller respond? If the seller beliefs that this signals that the true state is not H, then he should reject the offer. In period 1 he can get $2\delta\Delta$ by choosing $s(1)=v_L+\delta\Delta$ without concern about the lemons problem. However, if the seller beliefs and acts in this way the buyer has an incentive to lie and the seller suffers an lemons problem in period 1. (One has to deal with such considerations for $n_B(0)=1$.) This assumption excludes such paths as candidates for an equilibrium.

Remark B3

(a) The subsequent steps analyze best responses in period 0 for the cases where $\delta\leq\frac{c_1}{2\Delta}$ (Step 1), $\frac{c_1}{2\Delta}\leq\delta\leq\frac{c_1}{\Delta}$ (Step 2) and $\delta\geq\frac{c_1}{\Delta}$ (Step 3).

(b) If $n_B(0)=0$, Proposition 2 shows that the uninformed buyer has to account for the endogenous lemons problem and submits $b(0)\leq v_{0L}+\Delta$ since $c_0<\frac{1}{4}(v_H-v_L)-\Delta$.

(c) Given Remark A1, B1 and B2, if the buyer is informed it suffices to focus on offers which make the seller indifferent by giving him his continuation payoff.

Step 1 : $\delta\leq\frac{c_1}{2\Delta}$.

From Lemma 1, the default option D of the seller is D=0 if $n_B(0)=0$ and $D=\delta\Delta$ if $n_B(0)=1$.

Step 1.1 (Seller's best response correspondence in period 0)

Case 1: $n_B(0)=0$. Define $\hat{b}\equiv v_{0L}-\Delta-2\delta\Delta+2c_0<\frac{1}{2}(v_{0L}+v_{0H})-\Delta$.

(i) If $b=\hat{b}$ then the seller is indifferent between choosing $n_S(0)=0$ and $s(0)=N$ and choosing $n_S(0)=1$ and $s_L(0)=Y$ and $s_H(0)=N$. If the seller chooses the first response no trade occurs in period 0. In period 1 there is also no trade and $U^S=0$. If the seller chooses the second response then trade occurs in state L and $U^S=(v_{0L}-\Delta-2\delta\Delta+2c_0-(\Delta-v_{0L}))-c_0=-2\delta\Delta+c_0\geq0$ (since $\delta\leq\frac{c_1}{2\Delta}$). In state H no trade occurs in period 0. In period 1 the informed seller gets $U^S=2\delta\Delta-c_0\leq0$. So his expected payoff $EU^S=0$. (ii) If $b<\hat{b}$, then the best response of the seller is to choose $n_S(0)=0$ and $s(0)=N$ and $U^S=0$. (iii) If $b>\hat{b}$ then the seller chooses $n_S(0)=1$ and $s_L(0)=Y$ and $s_H(0)=N$ and $EU^S>0$.

Case 2: $n_B(0)=1$. Define $\hat{b}_L\equiv v_{0L}-\Delta+\delta\Delta$ and $\hat{b}_H\equiv v_{0H}-\Delta+\delta\Delta$.

Given Remark A2, the seller does not acquire information. It is easy to see that the best responses of the *uninformed* seller are given as follows. (i) If $b_L(0)=\hat{b}_L$ and $b_H(0)=\hat{b}_H$ then the seller is indifferent between $s(0)=Y$ and $s(0)=N$. (ii) If $b_L(0)>\hat{b}_L$ and $b_H(0)\geq\hat{b}_H$, or $b_L(0)\geq\hat{b}_L$ and $b_H(0)>\hat{b}_H$ then the seller's (weakly) best response is to choose $s(0)=Y$. (iii) If $b_L(0)<\hat{b}_L$ and $b_H(0)\geq\hat{b}_H$ or $b_L(0)\geq\hat{b}_L$ and $b_H(0)<\hat{b}_H$ then the seller chooses $s(0)=N$.

Step 1.2 (Buyer's decision in period 0)

(a) Suppose $n_B(0)=0$. If the buyer chooses alternative (i) then $EU^B=\Delta-c_0+\delta\Delta$. If the buyer chooses alternative (ii) then $U^B=0$. If he chooses alternative (iii) then $EU^B<\Delta-c_0+\delta\Delta$.

(b) Suppose $n_B(0)=1$. It is easy to see that a best response of the buyer is to choose $b_L(0)=v_{0L}-\Delta+\delta\Delta$ and $b_H(0)=v_{0H}-\Delta+\delta\Delta$ and $U^B=2\Delta-c_0-\delta\Delta$.

Consequently, the buyer compares the alternatives (ai), (aii) and (b).

Case 1: If $\delta<\frac{1}{2}$ then alternative (b) dominates (ai). The buyer compares (b) with (aii). If $\delta<2-\frac{c_0}{\Delta}$, the buyer chooses (b) and $U^B=2\Delta-c_0-\delta\Delta$. If $\delta>2-\frac{c_0}{\Delta}$, the buyer chooses (aii) and $U^B=0$. If $\delta=2-\frac{c_0}{\Delta}$, the buyer is indifferent between the two alternatives.

Case 2: If $\delta>\frac{1}{2}$ then alternative (ai) dominates (b). The buyer compares (ai) with (aii). If $\delta>\frac{c_0}{\Delta}-1$, the buyer chooses alternative (ai) and $EU^B=\Delta-c_0+\delta\Delta$. If $\delta<\frac{c_0}{\Delta}-1$, the buyer chooses alternative (aii) and $U^B=0$. If $\delta=\frac{c_0}{\Delta}-1$, the buyer is indifferent between the two alternatives.

Case 3: If $\delta=\frac{1}{2}$ then the buyer compares (ai, aii) with (b). If $\delta>\frac{c_0}{\Delta}-1$, the buyer is indifferent between (ai) and (aii) and $EU^B=\Delta-c_0+\delta\Delta$. If $\delta<\frac{c_0}{\Delta}-1$, the buyer chooses alternative (b) and $U^B=0$. If $\delta=\frac{c_0}{\Delta}-1$, the buyer is indifferent between the three alternatives.

Step 2: $\frac{c_1}{2\Delta}<\delta\leq\frac{c_1}{\Delta}$.

The seller's default option is $D=2\delta\Delta-c_1$ if $n_B(0)=0$ and $D=\delta\Delta$ if $n_B(0)=1$.

Step 2.1 (Seller's best response correspondence in period 0)

Case 1: $n_B(0)=0$. Define $\hat{b}\equiv v_{0L}-\Delta+2\delta\Delta-2c_1+2c_0<\frac{1}{2}(v_{0L}+v_{0H})-\Delta$.

(i) If $b=\hat{b}$ then the seller is indifferent between choosing $n_S(0)=0$ and $s(0)=N$ and choosing $n_S(0)=1$ and $s_L(0)=Y$ and $s_H(0)=N$. If the seller chooses the first response no trade occurs in period 0. In period 1 the seller gets $U^S=2\delta\Delta-c_1$. If the seller chooses the second response then trade occurs in state L and $U^S=(v_{0L}-\Delta+2\delta\Delta-2c_1+2c_0)-(v_{0L}-\Delta)-c_0=2\delta\Delta-2c_1+c_0>2\delta\Delta-c_1$. If $v_0=v_{0H}$, no trade occurs in period 0. In period 1 trade occurs with probability 1 and the seller gets $U^S=2\delta\Delta-c_0$. So his expected payoff is $EU^S=2\delta\Delta-c_1$. (ii) If $b<\hat{b}$, then the best response of the seller is to choose $n_S(0)=0$ and $s(0)=N$ and $U^S=2\delta\Delta-c_1$. (iii) If $b>\hat{b}$ then the seller chooses $n_S(0)=1$ and $s_L(0)=Y$ and $s_H(0)=N$ and $EU^S>2\delta\Delta-c_1$.

Case 2: $n_B(0)=1$. See Step 1.1 Case 2.

Step 2.2 (Buyer's decision in period 0)

(a) Suppose $n_B(0)=0$. If the buyer chooses alternative (i) then $EU^B=0.5(v_{0L}+\Delta-(v_{0L}-\Delta+2\delta\Delta-2c_1+2c_0))=\Delta-c_0-\delta\Delta+c_1$. If the buyer chooses alternative (ii) then $EU^B=0$. If the buyer chooses alternative (iii) then $EU^B<\Delta-c_0-\delta\Delta+c_1$.

(b) Suppose $n_B(0)=1$. Then the buyer chooses $b_L(0)=v_{0L}-\Delta+\delta\Delta$ and $b_H(0)=v_{0H}-\Delta+\delta\Delta$, and $U^B=2\Delta-c_0-\delta\Delta$.

Consequently, the buyer compares the alternatives (ai), (aii) and (b).

Case 1: If $\delta>1-\frac{c_0-c_1}{\Delta}$, then (aii) dominates (ai). So alternatives (b) and (aii) remain. If $\delta>2-\frac{c_{01}}{\Delta}$, the buyer chooses alternative (aii) and $U^B=0$. If $\delta<2-\frac{c_{01}}{\Delta}$, the buyer chooses alternative (b) and $U^B=2\Delta-c_0-\delta\Delta$. If $\delta=2-\frac{c_{01}}{\Delta}$, the buyer is indifferent between the two alternatives.

Case 2: If $\delta<1-\frac{c_0-c_1}{\Delta}$, then (ai) dominates (aii). So alternatives (b) and (ai) remain. If $c_1>\Delta$ then the buyer chooses (ai) and $EU^B=\Delta-c_0-\delta\Delta+c_1$. If $c_1<\Delta$ then the buyer chooses (b) and $U^B=2\Delta-c_0-\delta\Delta$. If $c_1=\Delta$ the buyer is indifferent between the two alternatives.

Case 3: If $\delta=1-\frac{c_0-c_1}{\Delta}$, then the buyer is indifferent between (ai) and (aii). If $c_1>\Delta$ then the buyer chooses (ai) or (aii) and $EU^B=\Delta-c_0-\delta\Delta+c_1$. If $c_1>\Delta$ then the buyer chooses (b) and $U^B=2\Delta-c_0-\delta\Delta$. If $c_1=\Delta$ the buyer is indifferent between three alternatives.

Step 3: $\delta>\frac{c_1}{\Delta}$.

The seller's default option is $D=2\delta\Delta-c_1$ for both $n_B(0)=0$ and $n_B(0)=1$.

Step 3.1 (Seller's best response correspondence in period 0)

Case 1: $n_B(0)=0$. See Step 2.1, Case 1.

Case 2: $n_B(0)=1$. Define $\hat{b}_L\equiv v_{0L}-\Delta+2\delta\Delta-c_1$ and $\hat{b}_H\equiv v_{0H}-\Delta+2\delta\Delta-c_1$.

As before, the best responses of the seller are given as follows. (i) If $b_L(0)=\hat{b}_L$ and $b_H(0)=\hat{b}_H$ then the seller is indifferent between $s(0)=Y$ and $s(0)=N$. (ii) If $b_L(0)>\hat{b}_L$ and $b_H(0)\geq\hat{b}_H$ or $b_L(0)\geq\hat{b}_L$ and $b_H(0)>\hat{b}_H$ then the seller's (weakly) best response is to choose

$s(0)=Y$. (iii) If $b_L(0)<\hat{b}_L$ and $b_H(0)\geq\hat{b}_H$ or $b_L(0)\geq\hat{b}_L$ and $b_H(0)<\hat{b}_H$ then the seller chooses $s(0)=N$.

Step 3.2 (Buyer's decision in period 0)

(a) Suppose $n_B(0)=0$. If the buyer chooses alternative (i) then $EU^B=\Delta-c_0-\delta\Delta+0.5c_1$. If the buyer chooses the alternative (ii) then $U^B=0$. If the buyer chooses alternative (iii) then $EU^B<\Delta-c_0-\delta\Delta+0.5c_1$.

(b) Suppose $n_B(0)=1$. Then the buyer chooses $b_L(0)=v_{0L}-\Delta+2\delta\Delta-c_1$ and $b_H(0)=v_{0H}-\Delta+2\delta\Delta-c_1$ and $U^B=2\Delta-c_0-2\delta\Delta+c_1$.

Consequently, the buyer compares the alternatives (ai), (aii) and (b). It is easy to see that alternative (b) dominates alternative (ai). So alternatives (aii) and (b) remain. If $\delta>1-\frac{c_0-c_1}{2\Delta}$, the buyer chooses alternative (aii) and $U^B=0$. If $\delta<1-\frac{c_0-c_1}{2\Delta}$, the buyer chooses alternative (b). If $\delta=1-\frac{c_0-c_1}{2\Delta}$, the buyer is indifferent between the two alternatives.

Step 4 (Equilibrium paths)

If $\delta<\min\{\frac{c_1}{2\Delta},2-\frac{c_0}{\Delta},\frac{1}{2}\}$ then the set of PE is given as follows. In period 0 the buyer chooses $n_B(0)=1$ and $b_L(0)=v_{0L}-\Delta+\delta\Delta$ and $b_H(0)\geq v_{0H}-\Delta+\delta\Delta$ if $v_0=v_{0L}$; and $b_L(0)\geq v_{0L}-\Delta+\delta\Delta$ and $b_H(0)=v_{0H}-\Delta+\delta\Delta$ if $v_0=v_{0H}$. The seller chooses $n_S(0)=0$, $s(0)=Y$. In any SPE trade occurs in period 0 and $U^B=2\Delta-c_0-\delta\Delta$ and $U^S=\delta\Delta$. (*Proposition 7(ai)*)

If $2-\frac{c_0}{\Delta}<\delta<\min\{\frac{1}{2},\frac{c_1}{2\Delta}\}$ then the set of PE is given as follows. In period 0 the buyer chooses $n_B(0)=0$ and $b(0)<v_{0L}-\Delta-2\delta\Delta+2c_0$ and the seller chooses $n_S(0)=0$ and $s(0)=N$. In period 1 the seller chooses $n_S(0)=0$ and $s(1)>v_{1H}+\delta\Delta-2c_1$ and the buyer chooses $n_B(1)=0$ and $b(1)=N$. No SPE with trade exists. (*Proposition 10(i)*)

If $\max\{\frac{c_0}{\Delta}-1,\frac{1}{2}\}<\delta<\frac{c_1}{2\Delta}$ then the set of PE is given as follows. In period 0 the buyer chooses $n_B(0)=0$ and $b(0)=v_{0L}-\Delta+2c_0-\delta\Delta$ and the seller chooses $n_S(0)=1$ and $s_L(0)=Y$ and $s_H(0)=N$. If $v_0=v_{0L}$ trade occurs. If $v_0=v_{0H}$, there is disagreement. In period 1 the informed seller chooses $n_S(1)=0$ and $s_L(1)=v_{1L}+\delta\Delta$ and $s_H(1)\leq v_{1H}+\delta\Delta$ if $v_1=v_{1L}$; and $s_L(1)\leq v_{1L}+\delta\Delta$ and $s_H(1)=v_{1H}+\delta\Delta$ if $v_1=v_{1H}$. The buyer chooses $n_B(1)=0$ and $b(1)=Y$. In any SPE trade occurs with probability 0.5 in period 0 and $EU^B=\Delta+\delta\Delta-c_0$ and $EU^S=0$. (*Proposition 8*)

If $\frac{1}{2}<\delta<\min\{\frac{c_0}{\Delta}-1,\frac{c_1}{2\Delta}\}$ then the set of PE is given as follows. In period 0 the buyer chooses $n_B(0)=0$ and $b(0)<v_{0L}-\Delta-2\delta\Delta+2c_0$ and the seller chooses $n_S(0)=0$ and $s(0)=N$. In

period 1 the seller chooses $n_S(0)=0$ and $s(1)>v_{1H}+\delta\Delta-2c_1$ and the buyer chooses $n_B(1)=0$ and $b(1)=N$. No SPE with trade exists. (*Proposition 10(ii)*)

If $\max\{\frac{c_1}{2\Delta}, 1-\frac{c_0-c_1}{\Delta}, 2-\frac{c_{01}}{\Delta}\}<\delta<\frac{c_1}{\Delta}$ then the set of PE is given as follows. In period 0 the buyer chooses $n_B(0)=0$ and $b(0)<v_{0L}-\Delta+2\delta\Delta-c_1+2c_0$ and the seller chooses $n_S(0)=0$ and $s(0)=N$. In period 1, the seller chooses $n_S(1)=1$ and $s_L(1)=v_{1L}+\delta\Delta$ and $s_H(1)\leq v_{1H}+\delta\Delta$ if $v_1=v_{1L}$; and $s_L(1)\leq v_{1L}+\delta\Delta$ and $s_H(1)= v_{1H}+\delta\Delta$ if $v_1=v_{1H}$. The buyer chooses $n_B(1)=0$, $b(1)=Y$. In any SPE trade occurs in period 1 and $U^B=0$ and $U^S=2\delta\Delta-c_1$. (*Proposition 6(ii)*)

If $\max\{\frac{c_1}{2\Delta}, 1-\frac{c_0-c_1}{\Delta},\}<\delta<\min\{\frac{c_1}{\Delta}, 2-\frac{c_{01}}{\Delta}\}$, then the set of PE is given as follows. In period 0 the buyer chooses $n_B(0)=1$ and $b_L(0)=v_{0L}-\Delta+\delta\Delta$ and $b_H(0)\geq v_{0H}-\Delta+\delta\Delta$ if $v_0=v_{0L}$; and $b_L(0)\geq v_{0L}-\Delta+\delta\Delta$ and $b_H(0)=v_{0H}-\Delta+\delta\Delta$ if $v_0=v_{0H}$. The seller chooses $n_S(0)=0$, $s(0)=Y$. In any SPE trade occurs in period 0 and $U^B=2\Delta-c_0-\delta\Delta$ and $U^S=\delta\Delta$. (*Proposition 7(aii)*)

If max $\frac{c_1}{2\Delta}<\delta<\min\{\frac{c_1}{\Delta}, 1-\frac{c_0-c_1}{\Delta}\}$ *and* $c_1<\Delta$ then the set of PE is given as follows. In period 0 the buyer chooses $n_B(0)=1$ and $b_L(0)=v_{0L}-\Delta+\delta\Delta$ and $b_H(0)\geq v_{0H}-\Delta+\delta\Delta$ if $v_0=v_{0L}$; and $b_L(0)\geq v_{0L}-\Delta+\delta\Delta$ and $b_H(0)=v_{0H}-\Delta+\delta\Delta$ if $v_0=v_{0H}$. The seller chooses $n_S(0)=0$, $s(0)=Y$. In any SPE trade occurs in period 0 and $U^B=2\Delta-c_0-\delta\Delta$ and $U^S=\delta\Delta$. (*Proposition 7(aiii)*)

If max $\frac{c_1}{2\Delta}<\delta<\min\{\frac{c_1}{\Delta}, 1-\frac{c_0-c_1}{\Delta}\}$ *and* $c_1>\Delta$ then the set of PE is given as follows. In period 0 the buyer chooses $n_B(0)=0$ and $b(0)=v_{0L}-\Delta+2\delta\Delta-2c_1+2c_0$. The seller chooses $n_S(0)=1$ and $s_L(0)=Y$ and $s_H(0)=N$. If $v_0=v_{0H}$, there is disagreement. In period 1 the informed seller chooses $n_S(1)=0$ and $s_L(1)=v_{1L}+\delta\Delta$ and $s_H(1)\leq v_{1H}+\delta\Delta$ if $v_1=v_{1L}$; and $s_L(1)\leq v_{1L}+\delta\Delta$ and $s_H(1)=v_{1H}+\delta\Delta$ if $v_1=v_{1H}$. The buyer chooses $n_B(1)=0$ and $b(1)=Y$. In any SPE trade occurs with probability 0.5 in period 0 and $EU^B=\Delta-c_0-\delta\Delta+c_1$ and $EU^S=2\delta\Delta-c_1$. (*Proposition 9*)

If $\frac{c_1}{\Delta}<\delta<1-\frac{c_0-c_1}{2\Delta}$ then the set of PE is given as follows. In period 0 the buyer chooses $n_B(0)=1$ and $b_L(0)=v_{0L}-\Delta+2\delta\Delta-c_1$ and $b_H(0)\geq v_{0H}-\Delta+2\delta\Delta-c_1$ if $v_0=v_{0L}$; and $b_L(0)\geq v_{0L}-\Delta+2\delta\Delta-c_1$ and $b_H(0)=v_{0H}-\Delta+2\delta\Delta-c_1$ if $v_0=v_{0H}$. The seller chooses $n_S(0)=0$, $s(0)=Y$. In any SPE trade occurs in period 0 and $U^B=2\Delta-c_0-2\delta\Delta+c_1$ and $U^S=2\delta\Delta-c_1$. (*Proposition 7(b)*)

If $\delta>\max\{1-\frac{c_0-c_1}{2\Delta}, \frac{c_1}{\Delta}\}$ then the set of PE is given as follows. In period 0 the buyer chooses $n_B(0)=0$ and $b(0)<v_{0L}-\Delta+2\delta\Delta-c_1+2c_0$ and the seller chooses $n_S(0)=0$ and $s(0)=N$. In period 1, the seller chooses $n_S(1)=1$ and $s_L(1)=v_{1L}+\delta\Delta$ and $s_H(1)\leq v_{1H}+\delta\Delta$ if $v_1=v_{1L}$; and $s_L(1)\leq v_{1L}+\delta\Delta$ and $s_H(1)= v_{1H}+\delta\Delta$ if $v_1=v_{1H}$. The buyer chooses $n_B(1)=0$, $b(1)=Y$. In any SPE trade occurs in period 1 and $U^B=0$ and $U^S=2\delta\Delta-c_1$. (*Proposition 6(i)*) **QED**

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