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Reihe Ökonomie
Economics Series

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Rational Alternative Explanation

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January 2001

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Abstract

The endowment effect, status quo bias, and loss aversion are robust and well documented results from experimental psychology. They introduce a wedge between the prices at which one is willing to sell or buy a good. The objective of this paper is to address this wedge. We show that the presence of asymmetric information in a rational-agent framework can account for the endowment effect, status quo bias and loss aversion as well as psychology-based explanations proposed in the past.

Keywords

Endowment effect, status quo bias, loss aversion, asymmetric information, bid/ask spread

JEL Classifications

D81, D82, G22

Comments
We thank Sherwin Rosen for comments. The usual disclaimer applies.

Contents

1. Introduction

The discrepancy between the maximum willingness to pay for a good (WTP) and the minimum compensation demanded to part from the good (WTA) is a robust empirical observation in economics [Kahneman, Knetsch, and Thaler, 1990, 1991]. The measures of WTA exceeding the measures of WTP, however, cannot be explained by the neo-classical framework with smooth utility function like that in Thaler and Rosen (1976). The leading alternative explanations for the difference between WTP and WTA are the "endowment effect" [Thaler, 1980] which captures the overvaluation of a good due to possession of it; the "status quo bias" [Samuelson and Zeckhauser, 1988] which is the preference to remain at a current state; and "prospect theory" [Kahneman and Tversky, 1979] where losses impact the agent's utility more than gains of the same magnitude. According to Kahneman, Knetsch and Thaler (1991, pg. 205), "after more than a decade of research on this topic we have become convinced that the endowment effect, status quo bias, and aversion to losses are both robust and important." A large empirical literature, drawing on surveys and psychological experiments, confirms the existence of those effects in many different fields.[1]

The purpose of this paper is not to dispute the fact that the disparity between WTP and WTA exits but to provide an alternative explanation for these observations within a rational expectation framework. We show that a framework where rational agents face asymmetric information is able to explain the wedge between ask and bid prices without invoking psychology.

This paper is motivated by the following two observations. First, a note by Marvin

[1]See among many other Olsen (1997) for confirming prospect theory in the case of investment managers' risk perception, Benartzi and Thaler (1995) for addressing the equity premium, Thaler (1980), Thaler et al (1997) in compensating risk, Bowman, Minehart, and Rabin (1999), Bateman et al (1997) in household consumption pattern, Hoorens et al (1999) for wage differentials by training, van Kijk and van Knippenberg (1996, 1998), Franciosi et al (1996) for the offer/ask price disperity in exchange goods.

Kosters (1976) in responding to Thaler and Rosen (1976): "if poor information on differences in risk between occupations leads to a relatively greater emphasis placed by workers on wage prices when they make their wage/risk choices, differences in the quality of risk information could influence the observed wage/risk trade-off." Our paper tries to build on this intuition on the role of information in compensation issues. Second, Glosten and Milgrom (1985), who study the pricing strategy of an uninformed market maker facing potentially better informed traders, provide a good way of framing compensation issues within a rational-expectations setting. In their framework, asymmetric information leads to a gap between the market maker's bid and ask prices. Our approach, however, differs from that of Glosten and Milgrom (1985) in several ways. First, they assume the existence of an equilibrium whereas we characterize the conditions for the existence of an equilibrium in our framework. Second, the informed trader's valuation of the asset in their model incorporates a stochastic time discount factor, θ. Necessary conditions for the existence of an equilibrium are fairly restrictive. For example, the equilibrium ask price fails to exist if the informed trader observes θ and $\theta \leq 1$ (see Appendix).

To relate the WTP/WTA to the bid/ask literature, we use an endowment economy with one informed and one uninformed trader. The informed trader has some private information about the value of the traded asset; the uninformed trader posts prices at which he is ready to buy or sell the asset. By mapping the market maker's bid/ask framework into the WTP/WTA discrepancy literature, the paper is able to focus on the compensation issues using asymmetric information without using pyschology-based explanations.

Our results can be summarized as follows. With asymmetric information, the uninformed trader thinks that the informed trader with whom he might trade has private information about the true risks. When communicating the prices at which he is willing to trade, the agent takes into account that the informed trader will trade assets only at a profit. This leads to a wedge between the uninformed trader's buying and selling prices. This is analogous to the discrepancy between the WTP and WTA documented by Thaler (1980). When Thaler (1980) asks people directly how much they would be willing to pay to eliminate a one in a thousand risk of immediate death, and how much they would have to be paid to willingly accept an extra one chance in a thousand of immediate death, he reports that a typical answer was "I wouldn't pay more than 200 dollars, but I wouldn't accept an extra risk for 50,000 dollars."[2] The difference between the prices at which individuals are willing to take on more risk or reduce risk can be interpreted as a particular case of WTP/WTA discrepancy.

The next section introduces the model. Section 3 analyses the valuation gap when only the informed trader has private information. Also in section 3, we use numerical examples as well as an insurance example to illustrate our results. Section 4 looks at the case where both the informed trader and uninformed trader have private information to explain the valuation gap. Section 5 concludes the paper.

2. Model

The model features a static endowment economy where an informed agent and an uniformed agent trade an asset whose value z depends on a state variable X taking values 0 and 1. The informed trader observes a signal G correlated with X. The uniformed agent posts prices at which he commits to buy or sell units of the traded asset. The agents have rational

[2] Jones-Lee et al (1985) has a similar survery results. Using a sample of more than a thousand individuals, people are told to imagine they have to travel, and are presented three options; they can use the company-paid coach firm, in that case the risk of death would be 8 in 100,000. They can choose a safer coach firm, at an extra cost for them, or they can keep some of their company's travel expenses for themselves while using a less safe coach firm. The safer alternative would entail a risk of death of 2 to 4 in 100,000, the riskier alternatives a risk of death of 16 to 32 in 100,000. All of the people polled were willing to pay something to increase safety, but only 19 percent were willing to increase risk to save money.

expectations in the sense that they know the joint distribution of X and G and optimally use this information. The goal is to determine the equilibrium price. The absence of trade arises as an equilibrium outcome if the informed trader is not willing to trade at the prices proposed by the uninformed trader. The agents' objective functions are as follows.

- *Informed trader :*

  The informed trader observes a private signal G and is willing to trade with the uninformed trader if his conditional expected profit is positive. Let π be the informed trader profits, p the asset price, and Q^s the amount of assets supplied (Q^s can be negative). The informed trader's expected profit is

$$E[\pi|G] = (p - v)\, Q^s. \tag{2.1}$$

  where, $v = E\left[z\left(X\right)|G\right]$. If $p > v$, the informed trader would be willing to supply an infinite positive amount of assets. If $p < v$, the informed trader would be willing to supply an infinite negative amount of assets. If $p = v$, the supply of assets is undetermined.

- *Uninformed trader:*

  The uninformed trader takes into account that he will be able to buy (resp., sell) only if the informed trader is willing to sell (resp., buy). It may seem natural to make the informed trader the one that initiates the trade but it is in no way necessary. As long as the uninformed trader believes that his possible counterparty is better informed than he is, the results of the paper hold. Let $F = sign(p - v)$. The consume wants to maximize his expected utility function

$$E(U) = E\left[u\left(e + (z-p)\,Q^d\right)|F\right], \tag{2.2}$$

where u is the uninformed trader utility function and Q^d is uninformed trader's demand for assets. The uninformed trader takes into account that $F \geq 0$, if and only if $p \geq v$.

3. Private Information for one trader only

We begin our analysis of the valuation gap with the case when only the informed trader has some private information. The objective function of a risk-neutral uninformed trader is;

$$E(U) = E[e|F] + (E[z|F] - p)\;Q^d \tag{3.1}$$

Let's analyze the price at which the uninformed trader is willing to purchase assets. First, he takes into account that the informed trader is willing to sell only if $v \leq p$. Hence the conditional probability of low state that the uninformed trader will use in this case is $E[z|v \leq p]$, which is inferior or equal to p. If p is strictly greater than $E[z|v \leq p]$, the uninformed trader will not buy assets. Hence the only possible price at which the uninformed trader might be willing to purchase assets is $E[z|v \leq p]$. Symmetrically, the only possible price at which the uninformed trader might be willing to sell is $E[z|v \geq p]$. Such a price might not always exist. Conditions for existence are given below.

Proposition 1 *Let Y and G be two random variables and I be the indicator function.*

The conditional expectation of Y *on* $I[v \geq p]$ is

$$E[Y|I[v \geq p]] = \left\{ \begin{array}{ll} \frac{E[I[v \geq p]Y]}{P(v \geq p)} & \text{if } v \geq p \\ \frac{E[I[v < p]Y]}{P(v < p)} & \text{if } v < p \end{array} \right\}$$

Write $v = E[Y|G]$, $\underline{v} = inf(v)$, *and* $\overline{v} = sup(v)$. *Define* H *on* $(-\infty, \overline{v})$ *and* L *on* $(\underline{v}, +\infty)$ *by* $H(p) = E[Y|E[Y|G] \geq p]$ *and* $L(p) = E[Y|E[Y|G] \leq p]$.[3] *Then,*

1. $\underline{v} \leq L(p) \leq p \leq H(p) \leq \overline{v}$,

2. $H(p)$ *and* $L(p)$ *are non-decreasing functions of* p,

3. $H \to \overline{v}$, *when* $v \to \overline{v}$, $L \to \underline{v}$, *when* $v \to \underline{v}$.

Proof of Proposition 1: See Appendix

Proposition 2 *If* $\overline{v}$ *is finite, the function* H *on* $(-\infty, \overline{v}]$ *has a fixed point if and only if* v *reaches* $\overline{v}$ *with positive probability. If* $\underline{v}$ *is finite, the function* L *on* $[\underline{v}, +\infty)$ *has a fixed point if and only if* v *reaches* $\underline{v}$ *with positive probability. If* $\overline{v}$ *(resp.,* $\underline{v}$*) is not finite* H *(resp.,* L*) has no fixed point.*

Proof of Proposition 2: See Appendix

Proposition 1 and 2 can be summarized as follows. If v attains its minimum $\underline{v}$ with positive probability then $\underline{v}$ is the unique fixed point of L. At $\underline{v}$, the uninformed trader is willing to buy some assets. If v attains its maximum $\overline{v}$ with positive probability, then $\overline{v}$ is the unique fixed point of H. At $\overline{v}$, the uninformed trader is willing to sell. If v attains its boundaries with positive probability, then there are two prices (and two prices only), at which the uninformed trader is willing to transact; namely, $\overline{v}$ and $\underline{v}$. The uninformed

[3] with $\overline{v}$ included in the H's domain if $\overline{v}$ is finite, and $\underline{v}$ included in L's domain if $\underline{v}$ is finite.

trader's selling price is always higher than his buying price. In fact, the uninformed trader is willing to buy at the minimum possible price the informed trader would accept ($\underline{v}$), and he is willing to sell at the maximum possible price the informed trader would agree ($\overline{v}$). Even if H and L have no fixed points, $\overline{v}$ and $\underline{v}$ are close being the uninformed trader's buying and selling prices in the sense that $H(p)$ converges to $\overline{v}$ as p approaches $\overline{v}$, and $L(p)$ converges to $\underline{v}$ as p approaches $\underline{v}$.

The informed trader will transact only if his marginal profit is non-negative. Trade is possible only when the realization of v hits the upper or lower bounds of its distribution, then, both uninformed trader and informed trader are indifferent to the amount of assets exchanged. For exposition purpose, we present insurance and numerical examples for the valuation gap analysis in the following three subsections.

3.1. Example 1: Insurance

To model insurance in this framework, let e_1(resp., e_0) be the endowment at "low" (resp., "high") state, where $e_1 < e_0$. Let $X = 1$ (resp., $X = 0$) denotes the "low" or "accident" state and let z pay \$1 in that state and \$0 in the other. The insurance premium p is the price of the contract and is paid in all states of the world. The informed trader acts as the insurer and the uninformed trader as the insuree. Past literature has often considered that the insuree enjoys some informational advantage over the insurer. This may be the case for some insuree's idiosyncratic risk factors hidden from the insurer. However, insurance companies have the resources and the incentives to obtain precise estimates of the risk they take. Indeed, in the long run, only insurance companies that do so will survive in a competitive market place.

The present framework is also different from the one used by Thaler and Rosen (1976) in their analysis of wage/risk choice. In theirs, the agent can choose to work at a wage rate that depends on the probability of accident or death. Our paper features an endowment economy where the insuree can increase or decrease his coverage. Moreover, the insurer does not ask the agent how much he would pay to reduce the risk of death by a constant probability. Rather, the agent is asked at which prices he is willing to change his coverage. The insuree does not trade a higher or a lower risk of death or accident, instead, he trades amount of assets, which he can increase or decrease. The insuree communicates the price at which he is willing to increase or decrease his coverage.

With the minor changes presented above, the general set up can be modified so that the objective functions for the insurer and insuree are as follows.

- *Insurer:*

In the low state, the insurer pays out Q^s, while in both states, he gets $p\,Q^s$. The insurer's expected profit is

$$E[\pi|G] = (p - P(X = 1|G))\,Q^s. \tag{3.2}$$

where Q^s is the amount of insurance supplied. For the insurance example, the informed trader's valuation is $v = P(X = 1|G)$. If $p > P(X = 1|G)$, the insurer would be willing to supply an infinite positive amount of insurance. If $p < P(X = 1|G)$, the insurer would be willing to supply an infinite negative amount of insurance. Finally, if $p = P(X = 1|G)$, the supply of insurance is undetermined.

- *Insuree:*

Let $F = sign(p - P(X = 1|G))$. The consume wants to maximize his expected utility function

$$E\,(U) = P(X=0|F)\,u(e_0 - pQ) + P(X=1|F)\,u(e_1 - pQ + Q) \tag{3.3}$$

where u is the insuree utility function. The insuree takes into account that $F \geq 0$, if and only if $p \geq P(X=1|G)$.

When only the insurer has some private information then the objective function of a risk-neutral insuree is

$$E\,(U) = E[e|F] + [P(X=1|F)(1-p) - (1-P(X=1|F))p]\;Q^d \tag{3.4}$$

The insuree takes into account that the insurer is willing to sell only if $P(X=1|G) \leq p$. Hence, the conditional probability of accident that the insuree will use in this case is $P(X = 1|P(X=1|G) \leq p)$, which is inferior or equal to p. If p is strictly greater than $P(X = 1|P(X=1|G) \leq p)$, the insuree will not buy insurance. Hence the only possible price at which the insuree might be willing to purchase insurance is $p = P(X=1|P(X=1|G) \leq p)$. Symmetrically, the only possible price at which the insuree might be willing to decrease his coverage is $p = P(X=1|P(X=1|G) \geq p)$.

3.2. Example 2: Bernoulli signal

Suppose that the insurer's signal G takes the values 0 and 1.

Proposition 3 *The gap between the price at which the insuree accepts to lower his coverage and the price at which he is willing to increase his coverage is decreasing in the variance of G, increasing in the variance of X, and increasing in the correlation between G and X.*

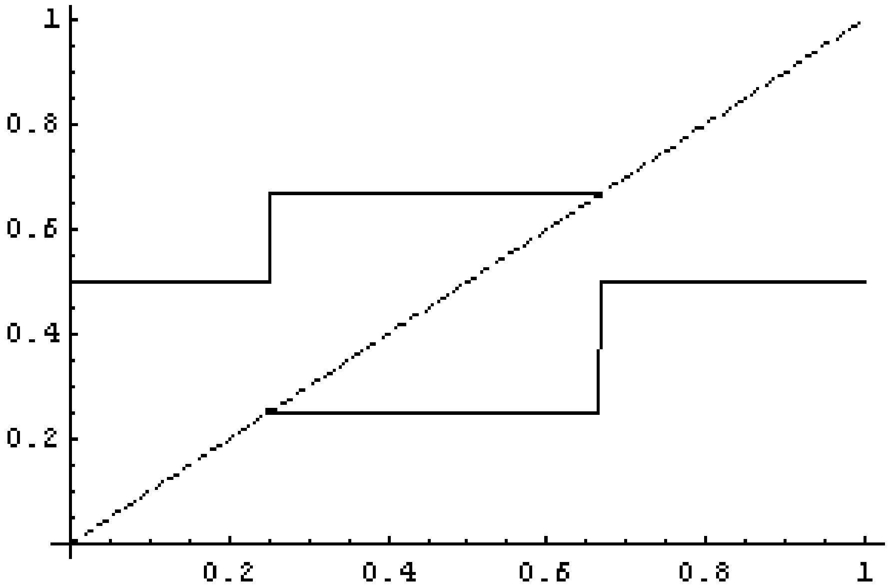

Figure 3.1: $L(p)$ and $H(p)$ when X and G are jointly Bernoulli with $P(X = 1, G = 1) = .4$, $P(X = 1, G = 0) = .1$, $P(X = 0, G = 1) = .2$, and $P(X = 0, G = 0) = .3$.

Proof of Proposition 3: See Appendix

Put another way, the gap between the insuree's selling and buying prices is an increasing function of the precision of the insurer's private information, measured by the correlation between X and G. This makes sense, the better informed the insurer is, the worse the adverse selection problem is for the insuree. The latter wants to protect himself by increasing the gap between buying and selling prices. Figure 3.1 graphs the function $H(p)$, and $L(p)$, when $P(X = 1, G = 1) = .4$, $P(X = 1, G = 0) = .1$, $P(X = 0, G = 1) = .2$, and $P(X = 0, G = 0) = .3$. In that case $P(X = 1|G)$ can take two values, 1/4 and 2/3. That is, there are two fixed points with the upper bound at 2/3 and the lower bound at 1/4: the valuation gap then being 5/12.

3.3. Example 3: Normally Distributed Signal

To illustrate that the valuation gap is robust to various distributions, we show our analysis using the Normal distribution. Suppose that the state-determining random variable X is generated by a random variable ξ , which is observed with error by the insurer. Specifically, $\xi \sim N(0, \sigma_\xi), X = I[\xi \geq 0]$, and $G = \xi + \eta$, with $E[\eta|\xi] = 0$. G, ξ and η are jointly normally distributed. The random variable $P(X = 1|G)$ does not attain its upper and lower boundaries with positive probability.

This implies that there is no equilibrium if the insuree is risk neutral or if he is perfectly diversified across states (i.e. $e_0 = e_1$) although the function $L(p)$ (resp., $H(p)$) converges to 0 (resp., towards 1), when $p \to 0$ (resp., $p \to 1$). If the insuree is risk averse, and $e_0 > e_1$, there is some price at which the insuree might buy assets, but there is no price at which he would sell. That is, at the posted prices, the insurer is indifferent between trading or not. This is comparable with the no-trade equilibrium of Milgrom and Stokey (1982). We conjecture that agents must have other motives to transact than private information for non-zero trade to exist in equilibrium. For exposition purpose, the functions H and L are graphed in Figure 3.2 with appropriate parameters.

4. Both insurer and insuree have some information; Bernoulli case

In this section, we analyze the valuation gap when both agents have some private information. Let H be the insuree's private signal and X and G retain their previous functions: X, G, and H take values 0 and 1 and are such that X is more likely to equal 1 when G or H equal 1.[4]

[4] Assume $P(X = 1|G = 1, H = 1) > P(X = 1|G = 1, H = 0) > P(X = 1|G = 0, H = 0)$ and $P(X = 1|G = 1, H = 1) > P(X = 1|G = 0, H = 1) > P(X = 1|G = 0, H = 0)$.

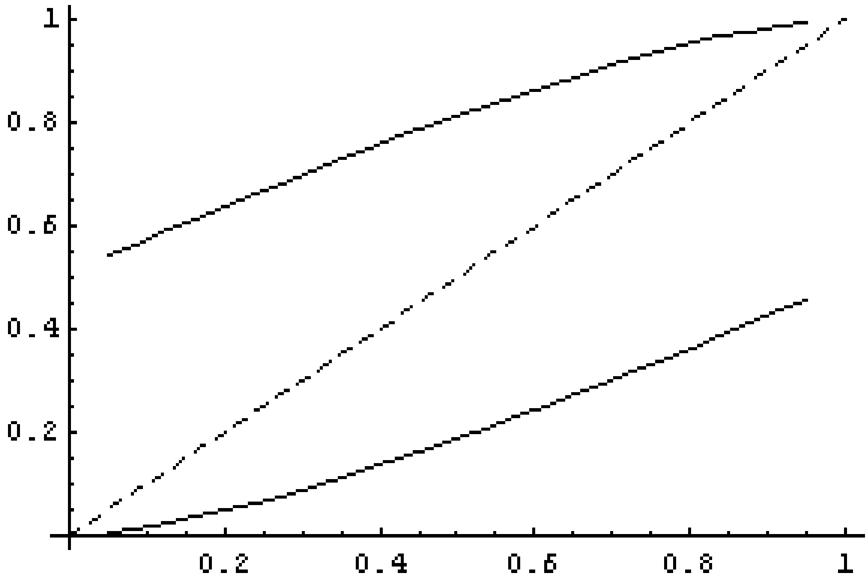

Figure 3.2: $P(X=1|P(X=1|G)\leq p)$, and $P(X=1|P(X=1|G)\geq p)$, with $\sigma_z=1/2$, $\sigma_\eta=1/3$.

The objective is to find the prices at which the insuree would be willing to reduce his coverage (call this price a) or increase his coverage (call it b). The insurer buys from the insuree if the insurer's valuation, v, is higher than a, and sells to the insurer if his valuation is lower than b. The random variable v depends on G and possibly on H itself if the insurer uses the prices quoted by the insuree to extract information about H. In all cases, we conjecture that the insurer buys ($v\geq a$) only if $G=1$ and sells ($v\leq b$) only if $G=0$. We later check that this conjecture is correct.

$$E[X|v\geq a,H]=P(X=1|v\geq a,H)=P(X=1|G=1,H)=\begin{cases}\frac{P(X=1,G=1,H=1)}{P(G=1,H=1)} & \text{if } H=1\\ \frac{P(X=1,G=1,H=0)}{P(G=1,H=0)} & \text{if } H=0\end{cases}$$

$$E[X|v\leq b,H]=P(X=1|v\leq b,H)=P(X=1|G=0,H)=\begin{cases}\frac{P(X=1,G=0,H=1)}{P(G=0,H=1)} & \text{if } H=1\\ \frac{P(X=1,G=0,H=0)}{P(G=0,H=0)} & \text{if } H=0\end{cases}$$

Hence, if $a = E[X|v \geq a, H]$ and $b = E[X|v \leq b, H]$, a and b depend on H. If the insuree's quotes differ when $H = 0$ and when $H = 1$, they reveal the realization of the random variable H.

If the insurer's expectations are rational, that is, if he uses all the information available, his valuation would be $E[X|a, b, G]$ and would coincide with $E[X|G, H]$. If the insurer does not exploit the information about H contained in the bid and ask quotes, his valuation would be $v = E[X|G]$ which is independent of H. In any case, call $\bar{v}$ the value of v when $G = 1$ and $\underline{v}$ its value when $G = 0$. Assuming that X is more likely to be 1 when G or H are 1, we have $\underline{v}(H) = b(H) < a(H) = \bar{v}(H)$ when the insurer is rational, which is consistent with his buying (selling) when $G = 1$ $(G = 0)$.

Like in the earlier case, at the posted prices, the insurer is indifferent between trading or not. However, in contrast with Milgrom and Stokey (1982), selling price and buying price here are different. The prices reveal the private signal of the insuree but not that of the insurer. The latter reveals the value of his signal by trading on the sell- or buy-sides. If the insurer is not rational, calling $a(H)$ and $b(H)$ the values of a and b as functions of H, $a(0) < \bar{v} < a(1)$ and $b(0) < \underline{v} < b(1)$.[5]

In that case, the insurer refuses to buy (sell) when $H = 1$ $(H = 0)$ but thinks he gains from trade when he does transact.[6]

As an example, we assume that X, G, H are generated by the latent, mean-zero, jointly normally distributed random variables, x, g, h where $X = 1$ if $x > 0$ and $X = 0$ if $x \leq 0$ and

[5] This is because $\bar{a} = P(X = 1|G = 1) = P(H = 0|G = 1)\, P(X = 1|G = 1, H = 0) + P(H = 1|G = 1)\, P(X = 1|G = 1, H = 1) = P(H = 0|G = 1)\, a(0) + P(H = 1|G = 1)\, a(1)$.

[6] That the bid and ask prices are the same when the insurer is rational and when he does not follow the Bernoulli distribution. When the insurer is not rational, the insuree knows that his ask (bid) will not be hit when $H = 1$ $(H = 0)$, so that, he could quote some other prices or nothing at all.

similarly for G and H. Assuming the covariance matrix of (x, g, h) is $\begin{pmatrix} 1 & 0.5 & 0.5 \\ 0.5 & 1 & 0.25 \\ 0.5 & 0.5 & 1 \end{pmatrix}$, we have the following results:

$$(a, b) = \begin{cases} (.79, .5) & \text{when } H = 1 \\ (.5, .21) & \text{when } H = 0 \end{cases}$$

and

$$(\bar{v}, \underline{v}) = (2/3, 1/3) \text{when the insurer is not rational.}$$

The gap between bid and ask prices is smaller when the insurer is rational (i.e. 0.29 vs. 0.33).

5. Conclusion

This paper studies whether the large discrepancy between the price that individuals demand as a compensation to increase risk and the price they are willing to pay to reduce risk can be explained within a rational expectation framework with asymmetric information. We base our model on Glosten and Milgrom (1985), who study the market makers' bid/ask spread using asymmetric information, to address the compensation issues.

In the present set-up, we use an endowment economy where agents trade assets in order to relate to the bid/ask (or WTP/WTA) literature. We let the insurer play the role of the informed trader, and the insuree take the role of the market-maker. We have to assume that the uninformed agent is risk neutral for him to communicate two prices. Then, his selling price is the highest possible price the insurer could accept while his buying price is the lowest possible price the insurer could accept. If the agent is risk averse, no price is high enough to entice him to take more risk. Therefore, the valuation gap is replaced by a refusal to trade on one side. We analyze the cases where (i) only the insurer and (ii) both the insurer and the insuree have private information with the random variable following Bernoulli and Normal distributions. For both cases, the equilibrium is of the no-trade variety when all agents are rational. This may be consistent with the Thaler's (1980) results and Lee-Jones et al (1985) study, where the majority of the people questioned in surveys failed to give a price that would compensate them for taking on more risk. We conclude that the asymmetric information framework used in this paper can explain the valuation gap without invoking psychology.

Appendix

Proof of Proposition 1:

1. To prove that $\overline{v} \geq H \geq p$, we have by definition,

$$H(p) = \frac{1}{P(v \geq p)} E[I[v \geq p]Y] \tag{5.1}$$

and,

$$\begin{aligned} E[I[v \geq p]Y] &= E[I[v \geq p]v] \\ &\geq E[I[v \geq p]p] \\ &= p(v \geq p)p \end{aligned} \tag{5.2}$$

To obtain the first line, write $Y = v + \eta$, with $E[\eta|G] = 0$. Then note that $E[I[v \geq p]\eta] = E[E[I[v \geq p]\eta|G]] = E[I[v \geq p]E[\eta|G]] = 0$, using the law of iterated expectations, and the fact that $I[v \geq p]$ is measurable with respect to G. To obtain the second line, note that $I[v \geq p]v \geq I[v \geq p]p$. For the third line, use the fact that p is a constant. Equation (5.1), and (5.2) imply that $H(p) \geq p$. As $v \leq \overline{v}$, $E[I[v \geq p]v] \leq P(v \geq p)\overline{v}$, and hence $H(p) \leq \overline{v}$. Likewise, $\underline{v} \leq L(p) \leq p$.

2. Let p_1, and p_2 in H's domain with $p_1 \leq p_2$.

$$\begin{aligned} H(p_1) &= \tfrac{E[v\ I[v \geq p_1]]}{P(v \geq p_1)} \\ &= \theta\ \tfrac{E[v\ I[v \geq p_2]]}{P(v \geq p_2)} + (1-\theta)\ \tfrac{E[vI[p_1 \leq v < p_2]]}{P(p_1 \leq v < p_2)} \end{aligned} \tag{5.3}$$

with $\theta = \frac{P(v \geq p_2)}{P(v \geq p_1)}$, $0 \leq \theta \leq 1$. As $\frac{E[v\ I[p_1 \leq v < p_2]]}{P(p_1 \leq v < p_2)} \leq p_2 \leq H(p_2)$, $H(p_1) \leq H(p_2)$. Now, let p in H's domain, $p \leq \underline{v}$, $I[v \geq p] = 1$, hence $H(p) = \frac{E[v\ I[v \geq p]]}{P(v \geq p)} = E[v]$. For L, proceed as follows.

$$L(p_2) = \lambda\ L(p_1) + (1-\lambda)\ \frac{E[v\ I[p_1 \leq v \leq p_2]]}{P(p_1 \leq v \leq p_2)} \tag{5.4}$$

with $\lambda = \frac{P(v \leq p_1)}{P(v \leq p_2)}$, $0 \leq \lambda \leq 1$. As $\frac{E[v\ I[p_1 \leq v \leq p_2]]}{P(p_1 \leq v \leq p_2)} \geq p_1 \geq L(p_1)$, $L(p_2) \geq L(p_1)$. Let p in L's domain, $p \geq \overline{v}$, $I[v \leq p] = 1$, hence $L(p) = \frac{E[v\ I[v \leq p]]}{P(v \leq p)} = E[v]$.

3. H is defined on $D_H = (-\infty, \overline{v})$, with the upper bound included if H is defined at that point. For all $p \in D_H$, $H(p) \leq \overline{v}$. The function H is an increasing and bounded on D_H, therefore H admits a limit, call it $limH$. $limH \leq \overline{v}$, and for all $p \in D_H$, $H(p) \leq limH$. Now suppose $limH \neq \overline{v}$, that is $limH < \overline{v}$. Then there is $\alpha \in D_H$, $limH < \alpha < \overline{v}$. As $H(p) \geq p$, for all $p \in D_H$, we have $H(\alpha) \geq \alpha > limH$. But this contradicts the property that, as H in non-decreasing and converges to $limH$, $H \leq limH$. One concludes that $limH$ cannot be different from $\overline{v}$, the same holds for L and $\underline{v}$. Q.E.D.

Proof of Proposition 2*:*

The proposition is proven for H, results for L can be derived in the same fashion. Suppose that $\overline{v}$ is finite, and that v attains $\overline{v}$ with positive probability. Assume that H has a fixed point p, let's prove that $p = \overline{v}$. By definition, $p \leq \overline{v}$. Suppose now that $p < \overline{v}$. Let α a positive scalar so that $p < \alpha < \overline{v}$, and $P(v \geq \alpha) > 0$. As $I[v \geq p] = I[v \geq \alpha] + I[p \leq v < \alpha]$, one gets

$$\begin{aligned} E[I[v \geq p]v] &= E[I[v \geq \alpha]v] + E[I[p \leq v < \alpha]v] \\ &\geq \alpha P(v \geq \alpha) + pP(p \leq v < \alpha) \\ &> pP(v \geq \alpha) + pP(p \leq v < \alpha) \\ &> pP(v \geq p) \end{aligned} \tag{5.5}$$

Hence, $p < \overline{v}$ cannot be a fixed point of H. Hence, the only possible fixed point of H is $\overline{v}$. Let's show that $\overline{v}$ is indeed a fixed point of H, i.e., that $E[I[v \geq \overline{v}]v] = P(v \geq \overline{v})\overline{v}$. The last equation follows directly from the fact that $I[v \geq \overline{v}]v = I[v \geq \overline{v}]\overline{v}$.

Suppose $\overline{v}$ is not finite, or that v does not attain $\overline{v}$ with positive probability. Then, the domain of H is $(-\infty, \overline{v})$. Let p be a candidate fixed point, then $p < \overline{v}$, but then, equation (5.5) shows that p cannot be a fixed point. Q.E.D.

Proof of proposition 3:

The signal G takes the values 0 and 1, with $P(G = 1) \in (0, 1)$. Let $p_{i,j} = P(X = i, G = j)$, $i \in \{0, 1\}$, $j \in \{0, 1\}$. $P(X = 1|G)$ takes two values $P(X = 1|G = 0)$, and $P(X = 1|G = 1)$. Suppose that $cov(X, G) \geq 0$ (this is harmless, if $cov(X, G) \leq 0$, one would substitute $1 - G$ for G and obtain a non-negative covariance), then $P(X = 1|G = 1) \geq P(X = 1|G = 0)$. Then, proposition (3) follows from the following lemma. Q.E.D.

Lemma 5.1. *$P(X = 1|G = 1) - P(X = 1|G = 0) = \frac{cov(X,G)}{var(G)} = \frac{\sigma_X}{\sigma_G}\rho_{X,G}$ where σ_X is the standard deviation of X, σ_G is the standard deviation of G, and $\rho_{X,G}$ is the correlation between X and G.*

Proof of Lemma *:*

$$
\begin{aligned}
P(X = 1|G = 1) - P(X = 1|G = 0) &= \frac{P(X=1,G=1)}{P(G=1)} - \frac{P(X=1,G=0)}{P(G=0)} \\
&= \frac{P(G=0)P(X=1,G=1) - P(G=1)P(X=1,G=0)}{P(G=1)P(G=0)}
\end{aligned}
\tag{5.6}
$$

Now, note that $var(G) = P(G=1)P(G=0)$, and that

$$\begin{aligned}
cov(X,G) &= E[XG] - E[X]E[G] \\
&= P(X=1, G=1) - P(X=1)P(G=1) \\
&= P(X=1, G=1) - [P(X=1, G=0) + P(X=1, G=1)]P(G=1) \\
&= P(G=0)P(X=1, G=1) - P(G=1)P(X=1, G=0)
\end{aligned} \tag{5.7}$$

This shows that $P(X=1|G=1) - P(X=1|G=0) = \frac{cov(X,G)}{var(G)}$. Of course, as $P(G=1) \in (0,1)$, $var(G) \neq 0$. Q.E.D.

Conditions for existence of an equilibrium in Glosten and Milgrom (1985)

The informed trader has a stochastic time discount factor, noted by θ. If x is the true value of the asset and G is the informed trader's private signal, then his valuation is $v = \theta\, E[x|G]$. Glosten and Milgrom then assume the existence of prices a and b such that $a = E[x|v \geq a]$ and $b = E[x|v \leq b]$. However, if θ is measurable with respect to G (i.e. the informed trader observes θ), then, equilibrium values of a and b may not always exist. If θ is measurable and $\theta \leq 1$, then $E[x|v \geq a] \geq E[\theta x|E[\theta x|G] \geq a]$; $\sup v$ is the only a such that $a = E[\theta x|E[\theta x|G] \geq a]$ and consequently there may be no a such that $a = E[x|v \geq a]$. Hence, a necessary—and rather odd—condition for the existence of an equilibrium ask price is that θ take values above 1 with positive probabilities, i.e., that the informed trader in some states of the world is willing to consume less if it means consuming later. (Conditions for the existence of a bid price can be derived in a similar way.) Assuming that θ is not measurable with respect to G means that the informed trader does not know at which rate he discounts time, which seems quite implausible.

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Authors: Dominique Y. Dupont, Gabriel S. Lee

Title: The Endowment Effect, Status Quo Bias and Loss Aversion: Rational Alternative Explanation

Reihe Ökonomie / Economics Series 92

ISSN: 1605-7996

ISSN: 1605-7996